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# OBSERVATIONS AND EXPERIMENTS ON MATING BEHAVIOR IN FEMALE MAMMALS

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## INTRODUCTION

MOST investigators of cyclic reproductive activity in female mammals have been more interested in the functional basis of the morphological changes and less interested in an analysis of the factors underlying the parallel changes in behavior. This inequality of emphasis probably can be attributed to the circumstance that the most stimulating of the early studies were initiated by anatomists and to the belief held for many years that external manifestations of heat are not sufficiently well defined to lend themselves to study by quantitative methods. As things have turned out, this early neglect of the behavioral responses is not altogether unfortunate because it has since become apparent that little progress could have been made had it not been for the splendid endocrinological background established by the experimental anatomists and the biochemists they enlisted in their aid. Only after this background was established, did it become possible to induce heat almost at will and to look forward to an investigation of factors involved in the regulation of its character and to a comparative study.

Heat and estrus, as the words are used here, refer to the physiological state of the female when she will permit copulation, but this criterion of heat has not always been insisted on. In the first modern investigations of reproductive activities when external signs of heat were thought to be absent or slight, the detection of a sequence of vaginal changes which recur at cyclic intervals and about the time of heat was regarded as a reliable test of the estrous condition in the guinea pig, mouse, rat and opossum (Stockard and Papanicolaou, 17, 19; Allen, 22, 23; Long and Evans, 22; Hartman, 23a). Consequently, in subsequent experimental studies in which these species were used, a vaginal smear picture devoid of leucocytes and composed of nucleated epithelial cells and cornified cells, or cornified cells alone, was frequently assumed to be diagnostic of heat in the absence of a mating test.

More often than not, this assumption was undoubtedly correct, but subsequent observations have revealed that in any



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investigation of mating behavior in which it is important to ascertain the beginning and end of heat or anything about its character, a more exact test is necessary. It has been shown, for example, that in several species the cyclic vaginal changes are of a type more or less distinct, but for one reason or another they are of doubtful value in the diagnosis of heat, viz., the dog (Evans and Cole, 31; Leathem and Morrell, 38, 39), the cat (Bard, 39), the sow (Wilson, 26), the cow (Hammond, 27; Cole, 30), the ewe (Grant, 34; Cole and Miller, 35; Höcker, 38), and the horse (Aitken, 27; Schtschjekin, 30), although Mirskaia (35) states that with rare exceptions cornified cells only were found during estrus in 45 mares.

In other species, even those in which the vaginal changes are most clearly defined, the condition normally associated with heat may be found in its absence, or heat may occur when its existence would not be suspected from the vaginal condition (Ishii, 22; Long and Evans, 22; Slonaker, 27; Smith and Engle, 27; Oslung, 28; Hemmingsen, 29, 33; Evans, Meyer and Simpson, 33; Witschi and Pfeiffer, 35; Ball, 36a, 37a; Young, Boling and Blandau, 41, for the rat; Smith and Engle, 27; Marrian and Parkes, 30; Voss, 30; Wiesner and Mirskaia, 30; Engle, 31; Lewis and Wright, 35; Snell, Fekete, Hummel and Law, 40, for the mouse; and Fellner, 32; Young, Dempsey and Myers, 35b; Young, 37, for the guinea pig).

A third reason for not relying on the vaginal test of heat in a study of mating behavior is that the vaginal changes normally associated with heat are not specific for heat. Evans and Bishop (22) and Evans (28) have shown that the constant cornification of the vaginal epithelium which results from vitamin A deficiency in the rat is not accompanied by a continuous state of heat, and Wade and Doisy (35) and Emery and Schwabe (36) have shown that the method of obtaining material from the vagina may produce complete cornification without other symptoms of heat.

Because the presence of certain cell-types in the vagina does not always indicate a willingness to copulate, much of the literature in which there is no proof of heat beyond the demonstration of vaginal estrus is not discussed in the review which follows. This omission is not intended to reflect any lack of appreciation of the past or prospective value of the vaginal smear technique for investigations of reproductive activities. In their studies of reproductive behavior the reviewer and those associated with him frequently employ this test routinely, but they find it necessary to rely on supplementary tests in order to be certain that the animals are sexually receptive.

### OBSERVATIONS ON THE CHARACTER OF MATING BEHAVIOR

Some information has been obtained about the mating behavior of representatives of all orders of mammals except the armadillos, manatees, and dolphins, whales and porpoises. Quite naturally we know most about species which are used in the laboratory, about those whose domestic value is such that a careful study of breeding habits has been encouraged, and about those which have been observed to breed in captivity in zoological gardens. Data which have been obtained from free-living forms are scanty at the best, but they are sufficient to indicate that an essential similarity exists between the main features of behavior observed under laboratory and natural conditions. They also give us glimpses here and there which contribute to the assembling of a comparative picture.

*The albino rat*

The non-pregnant albino rat comes into heat at intervals of four to five days throughout the year and usually after 6 p.m. When she is not willing to accept copulation, the female pays no attention to the male and if approached too closely may defend herself violently with one hind leg or even fight if the male is aggressive (Stone, 22; Wang, 23; Hemmingsen, 33). The beginning of heat is rather abrupt, and after an initial period of relatively intense responses, there is a more gradual return to a loss of sexual interest. The movements during this period are quick and darting, often in hops accompanied by a quivering of the ears or the entire body, and the female does not run away from the male, except that following a moment of smelling or licking by the male, she runs forward a short distance and halts where she is usually overtaken and caught in the copulatory clasp. When mounted by the male or fingered on the hindermost part of the back and around the base of the tail a lordosis or opisthotonus is shown which consists of an arching of the back brought about by depressing the lumbar and elevating the sacro-coccygeal region (Long and Evans, 22; Stone, 22; Wang, 23; Warner, 27; Hemmingsen, 33; Ball, 37a; Blandau, Boling and Young, 41). Hemmingsen regards this behavior as an invariable criterion of heat, but because of the observation by Long and Evans that a slight lordosis may be elicited at any time during the cycle by firmly inserting a speculum into the vagina, he questions that lordosis without the quivering of the ears and the darting movements is a sufficient proof of heat. It may be that females from which only a weak lordosis can be elicited, will not always mate, but Blandau, Boling and Young have found that when a strong lordosis is given the female will mate regardless of the other responses.

In addition to the above described characteristics of the estrous period, there is an increased muscular or running activity (Wang, 23, 24; Slonaker, 24, 27). One of Slonaker's rats ran as much as 38 miles during a 24-hour period which is assumed to have included the period of heat. This running activity, like the epithelial changes in the vagina, may be displayed in the absence of heat (Hemmingsen, 33; Hemmingsen and Krarup, 37b), but usually the peak of activity coincides with the time of heat.

Many variations in the character of the responses and in the length of heat are shown from animal to animal and from cycle to cycle in the same animal, although in a group of animals observed over 7 and 8 consecutive heat periods a considerable consistency of behavior was shown (Blandau, Boling and Young, 41). Often a more intense response is given to an aggressive male (Stone, 22; Hemmingsen, 33; Ball, 37a). The differences that are shown do not limit the usefulness of behavioral signs in the identification of heat. On the contrary, they enabled Hemmingsen and Ball to establish carefully graded systems by means of which 12 intensities of estrous responses can be determined and compared. In Hemmingsen's system the two lowest stages represent merely a decrease in unwillingness to comply with the male. The next higher two represent the lowest degrees of heat; the female shows a slight lordosis, but does not permit copulation. Beyond these stages there is an increasing willingness to respond to the male until, in the highest intensities shown, the female actually takes the initiative in placing herself demonstratively before the male or displays sexual excitement in the presence of normal females. In the opin-

ion of the reviewer, a simplification of the systems devised by Hemmingsen and Ball would be desirable, but apart from this adjudged fault they represent a beginning toward the study of sexual behavior by quantitative methods which is wholly admirable.

The length of heat in the rat is given as 4 to 8 hours (Ishii, 22), 3 to 12 hours (Long and Evans, 22), and 3 to 21 hours (Ball, 37a). The latter figures appear to be most nearly correct if we may judge from the average length of 13.7 hours, range 1 to 28 hours, determined by Blandau, Boling and Young (41).

The length and character of the estrous reactions may be affected by copulation although the point is by no means clear. Hemmingsen states that if a plug is allowed to form, the response of the female sometimes becomes antagonistic immediately afterward, but usually it will again show heat after a short while. Blandau, Boling and Young (41) found that the average length of heat was slightly but nevertheless significantly shorter in twelve animals which were allowed to mate at the beginning of heat. Neither set of observations, however, is completely convincing partly because allowance was not made for the possibility of a quantitative relationship between the amount of stimulation and the continuation of heat such as Ball (34a) found between the amount of stimulation and the production of pseudopregnancy.

A form of estrous behavior occasionally seen in albino rats is best referred to as male-like, mounting or homosexual behavior. When it is displayed the females act the part of the male by mounting other females and making all the movements of copulation except for rolling back and cleaning the genitalia afterwards (Long and Evans, 22; Hemmingsen, 33; Beach, 38b; Ball, 40). More recently, however, Beach (41) has seen untreated females execute the complete masculine pattern. In his earlier publication Beach (38b) suggests that mounting is associated with intense heat reactions, but Hemmingsen observed mounting by a female in which only a low degree of heat was being shown. Beach also notes that this "abnormal behavior" was not observed in the sexually experienced female, but no evidence for or against the validity of this observation is given by Long and Evans or Hemmingsen. The frequency with which this behavior is displayed was increased by injecting normal females with testosterone propionate (Ball, 40). The pattern differed from that displayed by untreated rats only to the extent that the genitalia were cleaned afterwards.

In addition to its cyclic occurrence in the non-pregnant rat, estrus is displayed by most animals soon after parturition. Earlier observations by Tsai (25) and Slonaker (25) yielded data which are less definite than those recently reported by Blandau, Jordan and Soderwall (40). The latter authors found that postparturitional heat was displayed by 27 of 29 animals, its length averaged 10 hours, which is somewhat less than that of heat periods in non-parturient females, and the length of the interval between the end of parturition and the beginning of heat averaged 18.5 hours, range 4 to 37 hours.

Occasionally estrus is displayed during pregnancy (Long and Evans, 22; Nelson, 29) and lactation (Slonaker, 25), but under such circumstances nothing is known about its character. It is merely reported that heat was displayed by one animal on the 4th and 14th days of pregnancy, by another on the 16th day, and by a third (Nelson's) on the 5th, 13th and 17th days of pregnancy. Slonaker states that mating tests made at some of the peaks of activity during lactation showed that the peaks

represented heat. The reviewer has found no reference to the occurrence of heat during pseudopregnancy.

Despite the extent to which the rat has been used in studies of reproductive activities, the relationship of the time of ovulation to heat has long been uncertain. Long and Evans concluded that in most animals ovulation occurs several hours after heat, but the results from a more recent investigation, in which the time of ovulation was related to the beginning of heat as determined by the willingness to copulate, have shown that in most animals ovulation occurs shortly before the end of heat. In a colony of animals in which the length of heat averaged 13.7 hours, no case was found in which ovulation had begun within six and one-half hours after the beginning of heat, but by the tenth hour it was complete in most animals (Boling, Blandau, Soderwall and Young, 41).

Heat without ovulation in normal appearing adult rats has only recently been described. In two animals in which ovulation had not occurred by the twelfth hour, microscopic examination of the ovaries disclosed that normal luteinization of the large follicles had not occurred and that ovulation would have been unlikely. In two other animals in which a longer interval elapsed between the beginning of heat and death, the evidence was even more convincing (Boling, Blandau, Soderwall and Young, 41).

Under experimental conditions, heat without ovulation has been reported in infantile rats. Mahnert (30) induced heat in 4-week old individuals by means of prolan injections. Ovulation was not induced, but corpora lutea-like bodies were present. The converse situation, namely, ovulation without heat in otherwise normal animals, has been described by Ishii (22), Hemmingsen (33) and Boling, Blandau, Rundlett and Young (41).

*Wild rats*

Descriptions of heat behavior have been found for three species of wild rats, the brown or Norway rat (Miller, 11), the Texas rice rat (A. Svihla, 31), and the wood rat (Wood, 35). They are rather sketchy but sufficiently complete to indicate that most of the elements of estrous behavior seen in the white rat are present in these wild species.

At least one, the brown rat, normally comes into heat after 5 p.m. The rice rat, if in heat, will go through characteristic mating reactions. If not, she will have nothing to do with the male and will fight him even to the point of killing him if he is too aggressive. The brown rat in full heat is also less pugnacious than at other times. When in heat both the wood rat and the rice rat take the initiative. After some preliminary sniffing, the female wood rat places herself directly in front of the male with her tail curved to one side. The female rice rat will follow the male about the cage, smelling of his genitalia until he turns and follows her. She then gives the appearance of starting to run away, but stops after taking a few steps and accepts copulation. The brown rat is more active when she is in heat than at other times.

The female brown rat is similar to the white rat in that the willingness to mate depends to some extent on the dominating ability of the male. Miller states that he never observed a female to mate with a male smaller than herself, but indicates that a pugnacious female, if placed with a larger male which could boss her, would mate without opposition.

Copulation does not appear to affect the length of heat in the wood rat or brown rat. A rice rat, on the other hand, is reported to have refused further attentions from the male after an initial period during

which several copulations took place, but it cannot be certain that this species was observed beyond what may have been an initial period of antagonism similar to that seen in the albino rat.

Postparturitional heat has been observed in the rice rat, the females of which mate within 10 hours after birth of the young (A. Svihla, 31). Heat may also occur in this species during lactation, for Svihla states that after several copulations, if she had a litter of young, the female went to her nest and nursed them.

### *The mouse*

The estrous behavior of the mouse is less definite than that of the rat; at least no reliable method for detecting the time of heat has been found which does not require a mating test. Consequently, less is known about the mouse than the rat. As in the latter species heat occurs at intervals of 4 to 5 days and is predominantly nocturnal (Lewis and Wright, 35; Snell, Fekete, Hummel and Law, 40). Its average length and range of variation are not known. According to Snell, Fekete, Hummel and Law, an estrous period of less than 24 hours is indicated; its length is perhaps nearer twelve hours. Certain species of mice may have the distinction of attaining sexual maturity sooner than any other mammal. Bailey (24) states that the female meadow mouse mates when she is 25 days old, and Hatfield (35) observed copulation in three females when they were 21 and 22 days old.

In several respects the behavior of the mouse resembles that of the rat. When the female is being pursued by the male, often after she has led him on (Svihla, 30, 32; Hatfield, 35), she will run a short distance and stop, immediately after which mating takes place. When she is being served by the male she frequently bends back her head and, in doing so, tends to display a lordosis. Non-estrous female meadow mice (Bailey, 24; Hatfield, 35), red-backed mice (Svihla, 30), and deer mice (Svihla, 32) are pugnacious toward the male and the reviewer's recollection is that the behavior of non-estrous white mice is not different.

The effect of copulation on heat is not clear. The red-backed mouse, deer mouse and meadow mouse are said to lose their desire to mate after a few copulations, although Bailey states that some meadow mice will accept attentions promiscuously. Hemmingsen observed 7 ridings in two hours in an albino mouse, but notes that the female squealed and sometimes ran away from the male. Decision is difficult, but some effect of copulation is suggested. As with the rice rat, however, the question arises if normal heat behavior may not be resumed after a short post-copulatory period of antagonism.

Heat within 12 hours postpartum is said to be the rule although heat was not found in two species of the deer mouse (Svihla, 32) and in the harvest mouse (R. D. Svihla, 31) immediately after birth of their litters. For species in which postparturitional heat is known to occur, nothing is known about its character.

Watt (31) describes a case of heat during pregnancy, but since the mouse was in a protracted labor, the reviewer is inclined to regard this as an instance of heat which ordinarily would have occurred postpartum. The best evidence for heat during pregnancy is that presented by Crew and Mirskaia (30) who report its occurrence in 6 of 100 pregnant females. In each of the 6 animals mating occurred only once and then (4th, 8th, 10th, 14th, 15th or 16th day) not always at a time when it would have been expected had the animals not been pregnant.

Data bearing on the time of ovulation with respect to heat have recently been

reported by Snell, Fekete, Hummel and Law. In the stock they used the interval between the onset of estrus and ovulation was quite variable, but as a rule probably did not exceed 2 or 3 hours. Since the length of heat may be about 12 hours, the implication is that ovulation occurs during the first half of heat. If this is true for all strains, the mouse differs in this respect from the rat.

The possibility that ovulation is not always accompanied by heat is suggested by Lewis and Wright (35). In their experiments eggs were recovered from ten animals which did not copulate and in which, presumably, heat did not occur. Their data also indicate that heat is sometimes shown in the absence of ovulation. Of 103 mice which copulated, no evidence of ovulation is reported in immature females following the implantation of anterior pituitaries (Engle, 31), and following the destruction of gametogenic tissue by x-ray treatment of the ovaries (Parkes, 26, 27a, 27b).

### *The guinea pig*

The estrous responses of the guinea pig are definite and easily recognized (Rein, 83; Miss Lathrop in Loeb, 14; Draper, 20; Ishii, 20; Tresidder, 22; Avery, 25; Louttit, 27; Young, Dempsey and Myers, 35b; Young, Dempsey, Hagquist and Boling, 37, 39). Lordosis which consists of a straightening of the back and an elevation of the pelvis is an unmistakable sign of heat when it can be obtained repeatedly. Frequently it is accompanied by a guttural vocalization and by the pursuit and mounting of other females and even males, but both types of behavior may be displayed independently of heat and therefore neither is a specific diagnostic of heat. The estrous responses are displayed most vigorously at the beginning of heat. Thereafter, they subside gradually until the end of heat when the animal again becomes repellent and by kicking vigorously with one hind leg or snapping with the mouth, fights away any advance by the male or any attempt to stroke her by the investigator. Differences exist in the intensity with which the estrous responses are given and in the length of time they can be elicited. Unfortunately, no method of evaluating the intensity of the responses has been worked out as Hemmingsen and Ball have done for the rat. Instead length of heat has been employed in measuring differences. It averages 8 to 9 hours, range 1 to 41.5 hours, although any heat longer than 20 hours is exceptional. From animal to animal a tendency exists for heat periods of a certain approximate length to be displayed (Young, Dempsey, Hagquist and Boling, 39).

In females in which heat tends to be long, it frequently is intermittent with intervals when the female will not mate inserted between periods of receptivity. This type of heat has been referred to as the "split estrus," a term which was perhaps not wisely chosen; "intermittent estrus" probably would be better.

As with the rat and mouse, the effect of copulation on heat is not clear. Tresidder seems to doubt that its course is affected by copulation, but Avery's data suggest heat is shortened. Young, Dempsey and Myers (35b) observed variable effects. Some animals remained in heat as if nothing had happened, others experienced a short post-copulatory refractory period during which lordosis could not be evoked, and in a third group heat appeared to be terminated.

Closely associated with heat in point of time is a male-like mounting activity which is displayed by approximately 90 per cent of the animals. Its maximum display usually coincides with the begin-

ning of heat (Young and Rundlett, 39). As with the rat, female guinea pigs which are showing this homosexual activity pursue other animals, mount them and display copulatory movements without licking their genitalia afterward. The extent to which mounting occurs varies from animal to animal, but in individuals there is a tendency to consistency from cycle to cycle. The extent of mounting is not related to the length or intensity of heat; in fact, at least two animals have been observed in which mounting activity displayed at 16- to 17-day intervals was unaccompanied by heat. It is not, therefore, an unfailing sign of heat. Furthermore, because it is seen so commonly in normal animals, caution should be observed in regarding it as evidence for a masculinization of behavior following x-ray treatment of the ovaries (Steinach and Kun, 31), or hybridization (Guyénot, Ponse and Wietrzykowska, 32), or as evidence for an inversion of sexual instincts by pre-natally injected male hormones (Dantchakoff, 38).

Investigators have long been aware of the occurrence of estrus shortly after parturition in the guinea pig, and prior to the development of the vaginal smear technique by Stockard and Papanicolaou (17, 19), the time of parturition was generally depended on as a point of departure for investigations of reproductive activity in this species. Oddly enough, though, relatively little precise information was obtained with respect to the frequency of postparturitional heat and its character compared with heat in the non-pregnant animal. Ishii (20) reported it as being displayed within 7 hours after parturition in 18 of 20 animals. He thought of it as being a less vigorous heat, but on the whole of longer duration than normal heat. Tresidder observed copulation in 12 animals immediately after parturition. Additional data have recently been obtained (Boling, Blandau, Wilson and Young, 39), which indicate that postparturitional estrus is of less frequent occurrence than heat in non-pregnant animals, that the interval between the end of parturition and the beginning of heat is usually less than two hours, and that its average length, 3.5 hours, is less than half that in non-pregnant individuals.

The theoretical possibility that heat occurs during pregnancy in the guinea pig is suggested by Nicol's (33) observation that in two of four pregnant animals typical estrous smears were obtained. The only instance which has come to the reviewer's attention in which there was known to be a willingness to mate is an unrecorded case which occurred in his own colony several years ago. Sixteen days after an artificial insemination which was subsequently shown to have been successful the vaginal membrane ruptured but estrus was not observed. On the forty-third day the animal was found in heat and artificial insemination was accomplished without incident. On the 58th day when the female was again examined, a well advanced pregnancy was detected and on the 71st day one normal young was born. The heat observed on the 43rd day of pregnancy was of normal vigor and mounting was displayed.

The guinea pig is one of the mammals in which heat occurs during lactation (Ishii, 20; Zuckerman, 32), but no observations have been made of its character.

The relationship of ovulation to heat in the guinea pig is quite definite. Although minor variations are encountered, there seems to be no question but that the end of heat is associated more closely with the time of ovulation than with any one vaginal condition (Young, 37), and

that ovulation occurs near the end of heat (Myers, Young and Dempsey, 36). The failure of heat at the time of ovulation is not uncommon, but in no one of 101 non-pregnant animals in which heat was observed and in which the ovarian condition was known was there a failure of ovulation (Young, Dempsey, Myers and Hagquist, 38). In six additional animals in which large follicles developed, but failed to luteinize and rupture, heat did not occur. Because of these observations the suggestion is made that the guinea pig is a species in which heat normally is dependent on ovulation or at least on follicular changes leading immediately to ovulation. The chief need for reservation is that heat is reported in x-ray treated animals (Genther, 31, 34) in which follicular development was incomplete. Unfortunately it is not known that estrogen was the only hormone being produced by these ovaries (Schmidt, 36).

### *The rabbit*

Although the state of heat can easily be recognized in the rabbit and this species has been used widely for investigations of reproductive activity, satisfactory data bearing on the conditions under which estrus is shown are lacking. The response given by the rabbit in heat bears considerable resemblance to that given by the rat and guinea pig. When jumped by the buck she elevates her hind quarters and raises the tail in such a way that the small of the back is depressed (Hammond and Marshall, 25). What would appear to be the slightest stimulus such as fingering the back or the approach of the buck is often sufficient to evoke the heat response (Fee and Parkes, 30; Büttner and Wienert, 35). Does which are not in heat when jumped will squat, arch the back, and draw in the tail between the legs in such a way that copulation is impossible. Often, too, they will attempt to raise the head and forelimbs in the corner of the cage thereby strengthening the squatting position and better avoiding the attentions of the male (Dr. Paul B. Sawin, personal communication). Aside from this, nothing has been found which would indicate that an antagonistic attitude is taken toward the male when the female is not in heat. The display of homosexual behavior is common.

According to Hammond and Marshall (25) and Fee and Parkes (29) there is no regular estrous cycle and the rabbit will generally mate throughout the breeding season. Recent observations, on the other hand, discredit this older opinion. According to Reynolds (31), Büttner and Wienert (35), and Friedman (38), the periods during which rabbits will copulate are varied and uncertain. Büttner and Wienert suggest that the regularity or irregularity of these periods, as the case may be, depends on the sensitivity of the ovulating mechanism to the stimulus given by the advances of the male. Friedman states that estrous rabbits are obtained with greatest consistency if the choice is limited, not to isolated animals, but to healthy postpartum females, particularly if consideration is given an unfavorable seasonal factor during October and November. The problem is further complicated by the suggestion of a cycle of follicular activity estimated to be about 7 days in length (Shibata, 31; Büttner and Wienert, 35). It is evident, if the rabbit is to be fitted into a comparative picture, that systematic observations are needed which will include attempts to identify the hormonal factors involved, and attempts to correlate changes in ovarian structures with changes in behavior.

There is less uncertainty about other features of estrus. Copulation has no effect, the male is accepted repeatedly.

Interesting observations by Hammond and Marshall (25) cover the periods of gestation and lactation as well. Up to 12 hours after copulation, practically 100 per cent of the animals were receptive. Between the 12th and 30th hours the does began to go off heat and between the 33rd and 39th hours all refused to copulate. After this time increasing numbers copulated, from 22 per cent at the 40th hour to 100 per cent on the 14th day and later. Immediately after parturition all the animals mated, but during lactation the percentage in heat declined progressively and no doe came into heat between the 15th day and the end of the suckling period. Two exceptions were noted. If no more than one or two young were suckled, or if seven young were suckled no more than two hours a day, the lactating adult usually remained in heat. Hammond and Marshall, Reynolds, and Friedman report that pseudopregnant rabbits also accept the male, although with reduced frequency.

It is well known that ovulation in the rabbit depends on copulation. Heat, therefore, does not depend on ovulation or the follicular changes leading up to ovulation, but the presence of follicles above a certain minimum size does appear to be necessary. Büttner and Wienert report that the ovaries in three-fourths of their animals showing heat reactions contained follicles larger than 1.5 mm. in diameter and that in the remaining fourth the size was 1 to 1.5 mm.

In addition to the observations recorded above for the rat, mouse, guinea pig and rabbit, miscellaneous data are reported for a few other rodents. Mating is nocturnal in the golden hamster, ovulation follows in a few hours, there is no postpartum ovulation and a 2- to 4-weeks lactation anestrum occurs (Deanesly, 38). The gray squirrel is similar to the extent that there is no postparturitional heat and no heat during lactation (Deanesly and Parkes, 33).

Muskrats mate when they are partially submerged in water. Mating depends on the female. If she is not in heat coaxing is without effect, in fact, the male is fought off, but as soon as the female is willing to mate, she squeals and leads him to the water where several matings occur after which they wash themselves (Svihla and Svihla, 31).

In captive porcupines observed by Struthers (28) rutting was evidenced by a pairing of two individuals. After an initial period of indifference to each other the female took the initiative by following the male about the cage and sitting near him when he was inactive. Eventually he became very attentive, and frequently they went through the amusing exercise of rubbing noses. These activities continued for about two days when copulation occurred. It lasted for several minutes after which there was no repetition.

Beyond that brought together in the paragraphs above, there is little if any information about the heat responses of normal female rodents. Eventually generalization will be interesting and undoubtedly of comparative value, but for the present, such an attempt would be unwise if not impossible. We have knowledge of too few species and conspicuous differences are shown by those for which data exist.

### *The sheep*

During the breeding season which varies from one part of the world to another, depending partly on the breed and partly on climatic and nutritional conditions, the non-pregnant sheep comes into heat at about 16- to 17-day intervals. Unlike several of the rodents, in which heat is predominantly nocturnal, it may begin at

any time in the 24-hour period (Cole and Miller, 35; McKenzie and Terrill, 37).

Agreement is general that external signs of heat in the absence of a ram are variable and of little diagnostic value (Marshall, 04a; McKenzie and Phillips, 30; Grant, 34; Roux, 36; McKenzie and Terrill, 37). She may eat less than usual, stand apart from the others or even search for a ram. In other cases she may show no indications of heat until teased by the ram when she will stand and allow him to mount. Marked restlessness is not shown. Toward the end of heat a reluctance to stand for the teaser has been found and at this time there may be a preference for a particular teaser.

When not in heat the ewe may jump away immediately when approached by the ram, but more often, according to McKenzie and Terrill, she will stand, allow the male to sniff at the vulva, urinate and then move away quickly when the teasing actions start. At no time is there a strongly antagonistic reaction. The intensity of heat varies during the course of a single period. According to Grant the beginning is sharply demarcated, the end much less sudden. Roux also finds the beginning abrupt, but the end is gradual only in some animals. McKenzie and Terrill report that either end may be abrupt or gradual and that there are no indications one end is more abrupt or gradual than the other.

The average length of heat is anywhere from 27 to 40 hours, the extreme range recorded, 3 to 96 hours. Long heat periods are generally more intense than short ones (Grant, 34). Short heat periods may be experienced near the beginning and end of the breeding season (McKenzie and Terrill, 37), although Cole and Miller (35) found no indication that this is the case. The former authors also state that sterile copulation tends to shorten the duration of estrus. There is no record of homosexual behavior by normal ewes in estrus, but McKenzie and Terrill observed its occurrence in four ewes beginning about two weeks after daily injections of 200 R. U. Progynon-B were started. One of these ewes appears to have been spayed. In at least two of the remaining three the ovaries were present.

Postparturitional heat does not occur in the ewe (Quinlan and Maré, 31; Roux, 36). Heat during pregnancy has not been observed, but two fairly well authenticated instances of superfetation indicate that occasionally it may be shown. In a case described by A. D. B. Smith (27a) mating is thought to have occurred 28 to 40 days after the previous conception. In a case described by Grant, a second mating is estimated to have taken place about two months after the first. One instance of heat during lactation has been observed by Cole and Miller and they add that the vaginal smear of the lactating ewe indicates that this may be rather common.

The relationship of the ovarian changes to heat in the sheep has been carefully studied. There is agreement among the investigators cited above and Green and Winters (35) in addition, that ovulation occurs during the second half of heat, if not near its end. Furthermore, most have observed ovulation without heat, especially near the beginning and end of the breeding season, but there is less certainty about the occurrence of heat without ovulation. Marshall (01) states that in every case when a sheep was killed after estrus had been observed a corpus luteum was found. Grant reports that not one of the 400–500 mature ewes examined at the abattoir during the normal breeding season failed to show corpora lutea. On the other hand, McKenzie,

Allen, Guthrie, Warbritton, Terrill, Casida, Nahm, and Kennedy (33) state that ovulation did not occur at estrus in 8 per cent of the animals they observed (presumably 141). In the later article (McKenzie and Terrill, 37) it is noted, however, that two ewes which came into heat without ovulation were again in heat 4 and 4.5 days later when ovulation did occur.

The reviewer's interpretation of these results is that the first heat which was unaccompanied by ovulation probably was associated with the presence of one or more large follicles; and that either it was of the prolonged intermittent type caused by a delay in ovulation, or, the follicles responsible for it failed to mature after reaching the preovulatory level and were replaced at the time of the second heat by follicles whose maturation was completed. In either case, the observation could be reconciled with the conclusion that in the ewe heat does not occur without ovulation or at least in the absence of changes which normally lead to ovulation.

### *The cow*

The non-pregnant cow comes into heat at intervals of about 19 to 20 days. According to Hammond (27) the various symptoms are displayed best when a bull or other cows are present. At the beginning of heat the cow becomes restless. She twitches her tail frequently and often raises it. When at pasture she usually does not continue to feed, but wanders about the field and frequently goes off by herself or with another cow which she rides. When the bull attempts to mount her she will stand still and not run away as happens when an animal is not in heat. A cow in heat frequently lowers the hips and small of the back and raises the tail end. She will also frequently play with the bull by horning him or will stand and lick him and when separated from other cattle will "blar." There is usually a short period when the cow is coming into heat and a rather longer period toward the end when the symptoms are less marked; during the remainder of the period, no difference in intensity can be observed.

According to Hammond the duration of heat averages 17 hours, range 6 to 30 hours. Weber (10–11) observed that cows which showed an intense heat usually had longer heat periods than those in which the manifestation of heat was slight. He also states that the length of heat is not affected by copulation.

Cows in heat commonly jump other cows and bulls. This behavior reaches its extreme expression in nymphomania when the "whore-cow" not only mounts other cows and bulls repeatedly but may even attempt to mount other species including man (Williams and Williams, 21). When this pathological condition exists she perhaps "blars" more frequently than when she is in heat and in such a way that the call can scarcely be distinguished from that of the bull. As a rule such a cow will copulate at any time, but there are exceptions in which willingness to accept the bull is not continuous.

There is no postparturitional heat in the cow. The first heat occurs at a variable time after parturition, if the cow is milked, usually between 3 and 7 weeks later (Chapman and Casida, 37; Hammond, 27; Weber, 10–11). After this time heat occurs regularly. If the calf is suckled, the first heat may not occur until after three months. Occasionally cows show a return of heat after conception, but its appearance is irregular and usually it ceases to recur after the 3rd or 4th month, although rarely it is seen up to the 7th or 8th month (Williams and

Williams, 21; Strodthoff, 22; Hammond, 27).

Ovulation occurs about the end of heat (Williams and Williams, 21; Strodthoff, 22) or shortly after the end (McNutt, 24; Hammond, 27). According to Strodthoff who examined the ovaries by rectal palpation, either may occur without the other.

### *The sow*

In non-pregnant sows heat occurs throughout the year at intervals of approximately 21 days. According to Corner (21) the

> duration of estrus is commonly 3 days, during which time the sow exhibits excitement in the presence of the male, with ready acceptance of coitus. If no male is present, the sow will follow other females about the pen, sniffing at their genitals and frequently imitating the sexual act by "riding" the others. In a larger herd without boars the female in heat will often be found in a separate group apart from the others, where for hours at a time the exhibition of the sexual urge continues until at the end of 3 days, or occasionally longer, it subsides.

McKenzie (26) also calls attention to the restlessness of the sow which is in heat, but adds that some sows go through estrus without exhibiting restlessness. According to Altmann (39) the peak of activity occurs toward the end of estrus, and during estrus the animal is less combative. The heat period is not terminated or shortened by coitus (Corner, 19).

Data bearing on the time of the first heat postpartum, heat during pregnancy and heat during lactation are inadequate to give finality to the conclusions they suggest. As in the other ungulates for which information exists, there appears to be no postparturitional heat. According to Struve (11) the interval between parturition and the first heat is 4 to 9 days. According to Marshall and Hammond (25) the interval is between 30 and 60 days. Heat during pregnancy is uncommon if it occurs at all (Corner, 21). The possibility is suggested, however, by the fairly well authenticated report of a superfetation (A. D. B. Smith, 27b). The reviewer has found only one reference to the subject of heat during lactation. Marshall and Hammond state that as a rule the sow which is suckling a litter only rarely comes into heat until 5 to 6 days after the young are weaned.

There are few references to the ovarian changes and heat. It seems clear from Lewis' (11) data and the articles by Corner that ovulation usually occurs on the second day and therefore during the second half of heat. Whether or not ovulation occurs without heat is not known. From Corner's (19) statement that the ovaries of all sows killed during heat contained mature or recently ruptured follicles, it may be assumed that heat is usually if not always accompanied by ovulation.

### *The mare*

During the breeding season which may extend throughout the year when animals are maintained on a reasonably high plane of nutrition, heat in the non-pregnant mare recurs every 21 to 23 days. The estrous responses are described briefly by Satoh and Hoshi (33) and by McKenzie and Andrews (37) in a preliminary communication. They seem to be best observed in the presence of a stallion.

During the diestrum, according to McKenzie and Andrews, the mare resists any attempt of the stallion to approach or tease her by kicking actively if he approaches the hind quarters or by striking or even attempting to bite if he approaches from the front. As the period of heat nears, the mare still tries to repulse the stallion by kicking, but she does not show the higher degree of resistance displayed earlier in the diestrum. The first day of heat the mare no longer repells advances of

the stallion. She stands quietly as he approaches, and as he teases by smelling and gently biting her over the withers she raises her tail, but appears little interested in him. Urine may or may not be passed. After she has been in heat a day or more, she still raises her tail when the stallion begins to tease her, but she now stands quietly and permits the stallion to mount without difficulty. The vulva undergoes rhythmic contractions. An increase in the intensity of the reactions roughly parallels the growth of the follicles and and maximum receptivity is reached shortly prior to or following ovulation. Soon afterwards the mare passes into a condition of mild receptivity comparable to that displayed on the first day, if not into the actively resistant condition of the diestrum. Once heat has begun willingness to accept the male is not always constant. Satoh and Hoshi (33), McKenzie and Andrews (37) and Day (39b) have noted that the estrous responses may be given intermittently with ovulation at the end. Andrews states in a personal communication that the percentage of pregnancies in mares displaying this type of heat seems to be normal. There is no indication that homosexual behavior is ever shown.

The length of heat is reported to vary from 1 to 27 days, but to average 5 to 7 days (Aitken, 27; Schtschjekin, 30; Mirskaia, 35; McKenzie and Andrews, 37). According to Aitken and Schtschjekin breeding has no effect on its length.

In the mare what is known as the "foal heat" occurs relatively soon after parturition but not as soon as the postparturitional heat of rodents, seals (Elliott, 84; Rowley, 29), and certain insectivores (Brambell, 35; Brambell and Hall, 36, 39). According to Schtschjekin this heat may occur any time from the 5th to the 30th or 40th day, although more animals come into heat on the 9th to 11th day than at any other time. In the observations by McKenzie and Andrews, the mean length of the interval was 7.25 days, range 2 to 12 days.

Heat during pregnancy in the mare is of occasional occurrence (Marshall and Hammond, 25). Satoh and Hoshi are more definite. During 1929, 5 of 71 pregnant animals showed signs of heat; during 1930, 3 of 92; and during 1931, 6 of 96.

Numerous observations bear on the relationship between changes in the ovaries and heat. Agreement is general that ovulation occurs near the end. Ovulation without heat has been found in normal appearing mares (McKenzie and Andrews, 37; Satoh and Hoshi, 33) and in mares injected with gonadotropic hormones (Day, 39a). Most interesting, however, because the mare is the only spontaneously ovulating species thus far described in which it has been encountered so commonly, is the occurrence of heat in the absence of ovulation (Satoh and Hoshi, 33; McKenzie and Andrews, 37; Zavadowsky and Goldberg, 37; Day, 39b; and Day, 40, in the pony mare). McKenzie and Andrews state that an occasional female was receptive for a day during the diestrum and that in some mares there were no detectable follicles. Satoh and Hoshi refer to two types of heat without ovulation. One is of short duration and of weak intensity, and a follicle never develops completely. The other type is normal in appearance and duration and may be found about the end of the breeding season. A larger follicle is always found, but it degenerates instead of maturing. Zavadowsky and Goldberg assume that the sterile matings of frequent occurrence toward the end of the breeding season can be explained by the failure of ovulation.

Completion of the description of the

mating behavior of rodents and ungulates permits a brief comparison of the more noticeable features. In the opinion of the reviewer, such a comparison reveals at the outset that the similarities in the fundamental features of the behavior and the phenomena associated with it outnumber the differences. The chief differences appear to be the common occurrence of postparturitional heat in many rodents and the greater length of heat in the ungulates. The posture simulating a lordosis is assumed by species in both groups, restlessness is common, homosexual behavior is displayed by certain species, and, except for the rabbit, ovulation is spontaneous and usually occurs during the second half of heat, if not near the end. Whether or not these similarities are the expression of comparable heat-inducing mechanisms cannot be decided until the experimental procedures tried with success on rodents can be tested on ungulates.

### *The carnivores*

Of the carnivores for which data exist, all except the dog show a heat behavior which in one way or another is more elaborate from the standpoint of display than that encountered in the other orders.

The behavior of the cat has been described by Van der Stricht (11), Bard (34, 36, 39), Greulich (34), and Maes (39, 40a). Bard's (39) description is quoted:

> Feline estrual behavior may be divided into *courtship activities* and the *after-reaction*. The former includes playful rolling, excessive rubbing, a curious low vocalization (calling) not heard at other times, and crouching and treading. The estrual crouch is a most specific posture. Resting on chest and forearms with pelvis and tail elevated the animal tends to execute treading movements of the hindlegs. It is in this posture that the female accepts the male. Intromission is almost always signalled by a loud cry or growl which suggests anger or pain; some females utter a piercing shriek. The after-reaction, which follows any mechanical stimulation, penile or artificial, of the distal vagina consists in more or less vigorous rolling, sliding, rubbing, squirming and licking. Most animals will not again accept the male until the after-reaction has run its course. No trace of this response can be elicited by vaginal stimulation in cats which are in anestrus.
>
> Normally cats go into heat two or three times a year. The intervals are irregular. The duration of estrus varies greatly from individual to individual and in the same individual from time to time; the average lies between three and ten days. The best criterion of full estrus is of course successive acceptances of the male, but many cats display marked courtship activities for a day or more before they will permit a male to mount. Some cats engage in courtship activities quite spontaneously; for example, they crouch and tread even when isolated from all other animals and left quite alone. Others do not show the behavior unless they are in the presence of a male or receive some stimulation of the external genitalia or of the skin surrounding the vulva. When a cat is in estrus she responds to light rubbing or tapping of the genital region by crouching and treading or if already in a crouch, by treading. Many females, but not all, show this response when the loose skin of the nape of the neck is grasped to mimic the action of the male who on mounting always holds the female in this fashion.

According to Greulich (34), the periods of rolling are interrupted by intervals during which the animal licks the vulva and rubs itself vigorously, especially its head and back, against any suitable available object. This period of activity is followed by one during which the animal lies quietly on its side, often purring softly and opening and closing its front paws—behavior which is usually interpreted as indicating a feeling of contentment and well-being. If the animal had only just come into heat, or if it had been stimulated only once or twice, it would ordinarily submit willingly to a repetition of the procedure within 15 minutes to a half-hour after the beginning of the inactive phase just described.

Ovulation depends on the stimulus of copulation and terminates heat, but not

until 2 to 5 days have elapsed (Longley, 11; Courrier and Gros, 33; Liche, 39). If the cat is left with the male during this interval between the first copulation and the end of heat, many other copulations occur. If there has been a lack of service, heat may be prolonged to 10 days or more (Liche). Ovulation is said to occur from less than 25 to as long as 54 hours after copulation (Courrier and Gros; Greulich; Liche; Dawson and Friedgood, 40).

The ferret is another carnivore in which the heat period is terminated by copulation provided ovulation occurs. Otherwise, heat may last as long as four months (Marshall, 04a, 04b; Robinson, 18; Hammond and Marshall, 30). Another peculiarity of the ferret is the prolonged copulation during which the female is tightly clasped by the male and rolled around as though they were engaged in a wrestling match. According to Hammond and Marshall, it may take an hour or more after the first attempt is made before copulation is effected, and the actual time of union may vary from 5 minutes to 2 hours, 55 minutes. When coitus is successful, ovulation follows in about 30 hours (Hammond and Walton, 34).

In the otter copulation is prolonged as in the ferret and accompanied by a vocalization encountered thus far only in the carnivores. Cocks (81) describes a case in which a pair mated in the water July 17th, the female chattering loudly and whistling in a peculiar way all the while. They remained thus for about an hour, swimming the entire time. August 12th they again paired in the water. They remained together on this occasion between an hour and an hour and a half.

Wight (31) describes the heat and mating behavior of the skunk in which many of the elements which are apparently common to the carnivores can be recognized. He states that the proestrum is indicated by complaining cries which presumably result from the male's attempt to copulate. In each attempt, the male seeks the female and engages in a struggle which appears ferocious, but which in reality is little more than a gesture. Each attempt varies from 5 to 10 minutes and terminates when the male voluntarily leaves the female without having completed copulation. During estrus an initial struggle accompanied by a massaging or titilation by the male is quickly followed by assumption of the receptive attitude which involves an elevation of the tail. In a case Wight observed, successful matings were made over a 51-hour period. They varied in duration from 5 to 20 minutes. During the last mating the female began to growl before being released by the male. From this time on he was constantly on guard and moved away to preen himself. The female also preened herself; the only time she did so after copulation and it apparently indicated the end of heat.

The heat behavior of the dog presents many features which differ, not only from the other carnivores, but also from the other mammals. The essential details are taken from Evans and Cole (31).

> At the beginning of prooestrum as determined by the escape of blood-tinged fluid from the vulva, males are invariably attracted. While we do not know whether persistent following would take place at so early a period, this soon becomes the case, even though during most of the prooestrum the female is actually hostile to the attentions of males. A day or two before the close of this epoch, i.e., a day or two before she accepts coition, a marked change in her demeanor is noticeable. At this time she will then endeavor to attract the attention of males by quick darting movements and stamping of the forefeet. During the first two days of active oestrum a maximum expression of sex desire on the part of the female is evidenced. Postural invitation to coitus is unmistakable. There is then a gradual recession of her interest from day three to the end of oestrus. During

the last day or two of oestrum, repellent actions on her part are usually evidenced, though with persistence on the part of the male, copulation is finally permitted.

Elsewhere they state that the length of estrus in 12 animals varied from 4 to 13 days, that ovulation is spontaneous and occurs early in estrus, usually on the second day, and that the dog continues in heat for somewhat more than a week after ovulation. With respect to spontaneous ovulation and the length of heat after ovulation, the dog and possibly other Canidae such as the silver fox (Rowlands and Parkes, 35) differ from the cat and ferret. In these species ovulation is not spontaneous and heat is terminated about the time of ovulation.

The relationship between the time of ovulation and heat in the dog differs from that in other spontaneously ovulating mammals. In every mammal of this type for which data have been found, except possibly the mouse, ovulation occurs during the second half of heat, if not near its end. If there is a failure of ovulation after the pre-ovulatory changes have begun, as in the cow and horse, heat persists as nymphomania (Williams and Williams, 21). Normally and pathologically, therefore, in spontaneously ovulating mammals the end of heat is closely associated with ovulation. Yet in the dog the temporal relationship is different, ovulation occurs near the beginning of heat and heat continues for a week or more. The implication is that the heat-inducing mechanism in the dog is different from that in other spontaneously ovulating mammals. A systematic investigation of the species, and of one or more other Canidae, would be of interest.

From the incidental data already cited and other information, it would seem that the heat period in carnivores is generally longer than that in rodents and ungulates. In addition to the data already given for the cat, ferret, skunk and dog, the tiger in zoological gardens is thought to have a heat period of about 8 days and that of wolves, jackals and foxes in zoological gardens is said to last 7 to 9 days (Heape, 1900). Rowlands and Parkes (35) state, however, that heat in the silver fox lasts only 3 to 4 days.

No suggestion has been found that homosexual behavior is ever displayed by the carnivores.

No data have been found bearing on the possibility of postparturitional heat except for Robinson's (18) reference to 2 ferrets which were in heat after parturition. Doubt is cast on this suggestion of postparturitional heat by Hammond and Marshall's (30) statement that the generative organs of a suckling ferret were in the anestrous condition 17 days after parturition and that a second animal whose young were killed immediately after birth did not begin to come on heat until 9 days later. The only instance of heat during pregnancy in an untreated carnivore is one recorded for the mongoose on the 24th day (Frere, 29). Its occurrence under experimental conditions following the injection of a pregnancy mare serum preparation into 3 pregnant cats is described by Windle (39). No evidence has been found that heat is ever displayed during lactation.

The occurrence of ovulation about 30 hours after copulation in the ferret and about 24 to 30 or more hours after copulation in the cat has been mentioned. Enders (40) suggests that in the mink, too, ovulation follows copulation or a similar stimulus in from 42 to 52 hours. How generally ovulation depends on copulation in carnivores other than the Canidae is not known. The prolonged copulation in the otter and the repeated copulations apparently indulged in by the skunk

(Wight, 31) and mongoose (Frere, 29) suggest that ovulation may also depend on the stimulus of copulation in these species. Correlation of follicular development with heat and copulation has been made for the ferret (Robinson, 18), dog (Evans and Cole, 31) and cat (Dawson and Friedgood, 40).

If the dog is excepted, the available information bearing on the heat behavior of the carnivores can be summarized in the form of several generalizations which must necessarily be tentative. Heat appears prior to the time of the ovarian changes which lead directly to ovulation and is generally long. Its display tends to be more elaborate than in the other groups. Copulation does not seem to shorten heat except as it stimulates ovulation with which the end of heat is associated. Copulation is frequently very much prolonged or at least repeated. Compared with the rodents and ungulates the interval between copulation and ovulation is long. Homosexual behavior has not been reported.

### *The infra-human primates*

Investigations of sexual behavior in infra-human primates went through an initial period when the opinion was held that in most representatives of this group, there is no recurrent period of heat, that females will accept the male whenever they are given the opportunity. This opinion is elaborated on most fully by Miller (28, 31). It appears to have had its origin in the report of sexual behavior given by Hamilton (14) for 18 macaque monkeys and 2 baboons, by Montané (16) for a pair of chimpanzees, by Hartman (28) for macaques and by Fox (29) for the orang-utan. Observations reported by Tinklepaugh (28) for *Macacus rhesus* might also have contributed to such an interpretation.

The necessity for modifying this conclusion soon became apparent because many investigators presented convincing evidence for the existence of cyclic periods of heightened sexual desire not only in the lower primates, such as the lemuroid, *Galago senegalensis moholi* (Lowther, 40), but also in the higher non-human primates. Gear (26) states that female Chacma baboons will not tolerate sexual advances of the males during the diestrum or metestrum, but that they permit and even solicit their overtures during the period of genital enlargement. Zuckerman (30, 32) confirms this conclusion to the extent that the desire for mating is greatest when the swelling of the sexual skin is the greatest, but he differs with respect to the willingness to mate during the diestrum. According to him, baboons seldom mate during the quiescent phase of the sexual skin, but a female is rarely observed to refuse the male. The grey-cheeked and sooty mangabey, the Moor monkey (*Macacus maurus*), and the pig-tailed macaque (*M. nemestrina*) appear to be more sexual than baboons during the quiescent phases of the perineal region. Nevertheless, the desire to mate is strongest at the height of the swelling, thus indicating a periodicity in these species. The same author agrees with others who have observed *Macacus rhesus* under laboratory conditions, that members of this species copulate at all times, but he is also convinced that mating is more frequent when the sexual skin is active. Hartman's agreement with this conclusion, and correction of his earlier opinion, is indicated by the statement in Ball and Hartman (35) that sexual excitability increases just before ovulation and falls thereafter, even though the drop is not usually so complete as to mean consistent refusal to mate. Periodicity of sexual behavior is also indicated for the Java macaque

(Spiegel, 30) and for the bonnet macaque (Hartman, 38). With respect to the latter species, Hartman states that the bonnets studied in the Carnegie colony are more restricted in their periods of receptivity than rhesus females. However, in view of data recently accumulated by Carpenter (in press), it is doubted that the bonnet macaque displays an estrus which is more sharply limited than that of *Macacus rhesus* under free range conditions. An article by Hamlett (39) contains no observations of behavior, but from his examination of the vaginal contents at various stages in the cycle he concludes that the species of Cebus monkey studied appear to copulate only at a definite time in the cycle. The existence of a definite estrous period in other New World monkeys is clearly indicated by the observations of Lucas, Hume and Smith (27) on the marmoset and by those of Carpenter (34, 35) on howler and red spider monkeys.

The best controlled observations on the great apes have been those on the chimpanzee by the Yale University group. They provide a substantial basis for the conclusion, suggested by Köhler (26) and Fox (29), that although copulation may be accomplished at any time during the cycle, it apparently is more interesting to both animals during the periods of genital swelling (Tinklepaugh, 30, 33; Elder and Yerkes, 36; Yerkes, 39a; Yerkes and Elder, 36).

The apparent explanation for the failure of early observers to detect the periodic change in sexual desire shown by infrahuman primates is that proper allowance was not made for the influence of certain nonsexual factors such as individual characteristics of the consorts, social relations and environmental circumstance which tend to obscure the manifestation of cyclic changes in reproductive behavior within this group. The influence of certain of these factors is obvious from the observations on the behavior of female chimpanzees in the presence of dominant males (Sokolowsky, 23; Schultz and Snyder, 35), but their importance is especially emphasized by Zuckerman (32), Yerkes (39a) and Yerkes and Elder (36).

After citing an experiment in which a reasonably homogeneous group of chimpanzees was tested, Yerkes and Elder state:

> . . . we may safely assert that when mating experiments are conducted with a homogeneous group of subjects and important factors are varied singly, the copulation distribution is transformed by limitation to the mid-third of the sexual cycle. This we have ventured to designate as the period of oestrus in chimpanzee. By varying the nature of the social relations among consorts, the maximal frequency of copulation may be shifted. . . . Thus, for example, if individuals unacquainted, uncongenial, or hostile be used as mates, copulation tends to extend into the first third of the cycle, and it may for certain consorts become coextensive with the cycle. For it clearly appears that receptivity may be completely overshadowed by the dominance and aggressiveness of the male or by the timidity and defensiveness of the female. Consequently, if in an experimental study of mating behavior, with interest in the existence, strength, and relations of sexual desire and receptivity, subjects are chosen irrespective of their social relations, developmental status, and sexual experience, extremely diverse and highly variable results should be expected, and it may very well appear that copulation is not limited to any phase of the sexual cycle.
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> . . . our data establish that in a given instance environmental stimuli may determine the mating pattern, either inducing positive response when it would not otherwise occur, or inhibiting it despite strong sexual desire in both consorts. . . . It appears similarly that such social factors as strangeness, hostility, devotion, may compete with primary physiological factors and in some instances dominate.

The importance of the physical characteristics of the consort is discussed elsewhere (Yerkes, 39a):

> The relationships exhibited by the table [estimates of age, physical and sexual vigor, penis length, and intelligence for 3 males] in conjunction with details of observation . . ., strongly support the generali-

zation that the sexual acceptability of M to F tends to vary directly with vigor, penis length, and copulational time and thrusts, and inversely with degree of sexual selectiveness, dominance and aggressiveness. . . . it appears that female preference in mates is dependent largely upon the physique and sexual behavior of the male.

Individual variations among males with respect to the influence of the sexual status and traits of the female are extreme. One male, for example, may consistently refuse to mate with a given female, or he may accept her only for a few days—almost certainly those approximating the time of ovulation . . .—during the normal sexual cycle. Another male, by contrast, may eagerly accept or even insistently solicit the same female throughout the three phases of genital swelling, and even when her sexual receptivity is very slight. Similarly, a female consort may consistently refuse one male and in the next minute eagerly mate with another. . . . In many of these cases of anomalous sexual behavior the essential condition seems to be social incompatibility, but this of course may trace to the influence of physique, of immediate behavior, or of preference for another mate over the one at hand.

Such a shifting of the frequency of copulation beyond the period of heat is unknown in the lower mammals. Its nearest counterparts are seen in the rat in which a more intense response is often given to an aggressive male (Miller, 11; Stone, 22; Hemmingsen, 33; Ball, 37a), and in the ewe toward the end of heat when there may be a preference for a particular teaser (Roux, 36).

Another characteristic of primate behavior which is not encountered in the lower mammals, and which tends to obscure the picture as far as the definition of an estrous period is concerned, is the use of the sexual responses as a means of obtaining material advantages such as food or protection from enemies (Hamilton, 14; Zuckerman, 32; Maslow, 36; Gillman, 39). Bingham (28) has added to this list the tendency to show off sexually in the presence of interested spectators.

The characteristics of female behavior during the period of heightened sexual desire have been described for the howler monkey (Carpenter, 34), the rhesus monkey (Carpenter, in press) and the chimpanzee (Yerkes and Elder, 36; Yerkes, 39a). Carpenter states that the external genitalia of the receptive howler female cannot be distinguished from the genitalia of non-receptive animals. Estrous females appear to be identifiable in the wild by their behavior during 4 or 5 days of the receptive period. They approach males in their group, display rhythmic tongue movements and assume provocative postures. In addition the female may lick the face and hands of the male. After copulation she may take a position on her back and roll several times from side to side. The female which has just mated also tends to remain closely associated with the male for several hours, or even a day or more, during which time a number of copulations usually occur. Subsequently, if the first male becomes satiated, which generally happens, the female becomes the consort of a second highly motivated male. The possibility of sexual activity outside of the estrous period cannot be excluded. Two observations were made which suggest that copulation occurs sporadically without repetition and without close association of the female and male.

Some of the most interesting data bearing on primate sexual behavior are contained in a field-study of *Macaca mulatta* which Dr. Carpenter has kindly permitted the writer to see in manuscript. Evidence is presented indicating that under the free ranging conditions on Santiago Island the estrous period is much more sharply defined than has previously been assumed from observations of the rhesus monkey under laboratory conditions. It lasted an average of 9.2 days with a range from 4 to 15 days and an average deviation of 2.90 days for 40 females who showed 45

estrous periods. The length is assumed to be regulated in part by physiological factors, but it is postulated that socionomic factors such as the sexual capacities and dominance characteristics of the male consorts, the presence of only one estrous female in the group, the intragroup dominance status of the female, strong attachments between specific males and females and "habit" perseveration supplement the physiological factors in lengthening or shortening estrus. Carpenter calls the extended behavioral estrus of females caused by one or more of these factors a "perseveration effect."

The onset of estrus is estimated to have a rapid rise in intensity, but the decrement at the end is more gradual. The peak of excitement is thought to occur on the second or third day. During the period of heightened sexual desire there is an increased general activity which is accounted for in part by the female's greater aggressiveness as she ascends the dominance scale. An estrous female in the initial phase of heat leaves her normal subgroup, and in the face of numerous vicious attacks by the males in the large group, approaches them, assumes a crouching posture and performs invitational gestures until one or more responds. She may then express intense sexual excitement by copulation, described as a series of mountings with intromission and several piston thrusts which is terminated by ejaculation, by rapid flexion and extension movements of the dominant hand and arm and by sham attacks on nearby females and young. An association is established between a receptive female and the male of the group with whom she is copulating which may last several days. The females observed by Carpenter had associations with an average of three males in each estrous period. During these associations the male and female are never more than a few yards apart, grooming is more persistent than during the diestrum and copulation as described above may occur three or four times a day. Estrous females do not always remain in their indigenous groups. Four of forty animals were observed to leave their groups and copulate with males in other groups. Following estrus the female remains in the same group, but she is less closely associated with males, the consort relationship ends and she again becomes a part of the cluster of females and young. Mounting with intromission was seen outside of estrus, but there were no persisting consort associations and such observations may have been of females just beginning or terminating a period of receptivity or of females seeking to avoid an attack or as a means of gaining some end. Data bearing on the relationship between ovulation and estrus have not yet been obtained, but a close association is indicated by Hartman's (32) statement that the rhesus monkey is much less ardent sexually during the summer season of anovulatory cycles. Homosexual behavior is reported as it had been previously by Maslow (36).

In the chimpanzee the willingness to mate is represented as gradually waxing, continuing at a maximum for a few days and then suddenly disappearing after ovulation. The tendency of the fully receptive female is to rush to the male and prostrate herself before him (Yerkes and Elder, 36; Yerkes, 39a). In addition these investigators list the anticipatory behavior while preparations for a mating experiment are in progress, the manner of presentation and the degree of coöperation in sexual union, and the efforts of the female to attract the attention of the non- or slightly responsive male by posture, gesture, vocalization and playful antics. Of frequent diagnostic value is the greater

friendliness displayed by some animals toward human observers. Among the animals themselves a change in the dominance-subordination relationship as measured by a food incentive is often observed (Yerkes, 39b, 40; Crawford, 40). Homosexual behavior is described (Köhler, 26; Bingham, 28; Yerkes, 39b), but Yerkes notes that the animals he studied, instead of mounting their companions as cows, sows and guinea pigs do, were mounted. The writer, on the other hand, has recently seen a female who had just presented mounted by another female with a maximal swelling in a manner which simulated male behavior in every detail except for the absence of the thrusts characteristic of normal copulation.

When the literature bearing on sexual receptivity during pregnancy is reviewed, it seems clear that sexual desire, if it is displayed at all, is exhibited by the pregnant female only during the first month or two of the gestation period (Ball, 37b, for *Macacus rhesus;* Zuckerman, 30, and Hartman, 38, for the bonnet macaque; and Zuckerman, 30, for the baboon). Zuckerman's statement, that a pair of pig-tailed monkeys copulated freely during the pregnancy of the female, has not, as far as the reviewer can ascertain, been confirmed or contradicted. In the chimpanzee mating has been observed throughout all or most of pregnancy (Montané, 16; Bingham, 28; Tinklepaugh, 33). Yerkes (39a) discusses the problem and concludes tentatively, "that pregnancy receptivity is an artifact, due to the reflection by the female of the sexual dominance of her consort."

The differences between the heat behavior of non-human primates and lower mammals can now be considered. Conspicuous and important is the extent to which non sexual factors such as fear, the desire for food or the desire to "show off" are dominating stimuli. Equally prominent are the individual characteristics of the members of a pair. Likes or dislikes which may be traceable to social incompatibility or peculiarities of physique appear to go far in modifying the response which would be expected if only the physiological status of the animals were involved. In the lower mammals, the dominance of a male may be decisive toward the end of estrus when the responses are normally difficult to elicit, but there is no record that any amount of aggressiveness will lead to mating when the female is physiologically unprepared for mating. The non-human primates appear to be the only infra-human mammals in which the time of copulation can be shifted outside the limits of the estrous period by psychological or environmental factors.

In this respect they would seem to bridge the gap between the lower mammals in which receptivity is displayed only at the time of heat and the human female. Interestingly enough, the change may have taken place within the Order. There appear to be primates such as the baboons, the rhesus monkey under free range conditions, and certain of the New World monkeys in which the periodicity of sexual desire is clearly evident. In others such as the rhesus monkey, under laboratory conditions and the chimpanzee the limits of the receptive period are less sharply defined, but upon careful observation cyclic changes in the degree of receptivity are seen.

*(To be concluded)*

# HOOK PATTERNS ON THE ACANTHOCEPHALAN PROBOSCIS

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AMONG the worms which have adopted the parasitic mode of life, no group has abandoned the paths of independent existence more completely than the Acanthocephala. They are so perfectly adjusted to parasitic habits that in normal development after hatching no individual ever passes even a brief interval outside the body of some host creature. Females, dwelling in the intestine of a vertebrate, discharge the fertilized eggs into the lumen of the host intestine. When these eggs, each bearing a developing embryo, reach the exterior along with the intestinal wastes of the host, even hatching is contingent on the egg being swallowed by some suitable animal. So far as known, this first host is always an arthropod in whose body the embryo becomes liberated from its shells. Within the body of this first host, development never proceeds beyond a certain point. During the sojourn in the arthropod, the young worm undergoes conspicuous metamorphosis wherein the beginnings of all organs characteristic of the adult acanthocephalon are laid down. It is during this residence in the arthropod host that the proboscis, which is the subject of this article, makes its appearance. The attainment of full growth and sexual maturity for the larval acanthocephalon is deferred until the sheltering arthropod is devoured by a suitable species of vertebrate in whose intestine the adult worm spends the remainder of its life.

As an accompaniment of such complete adjustment to parasitism, every member of this group has lost all traces of organs and systems reminiscent of independent life. They possess no organs of locomotion, no digestive organs, no highly specialized sensory apparatus and most of them lack all special excretory mechanisms. In fact, the body becomes little more than a sac for sheltering the reproductive organs and a proboscis for maintaining hold on the host tissues. The elimination of so many features, leaves a body of monotonous form with relatively few avenues available for expression of taxonomic characters.

In spite of this drastic reduction in number of morphological features available for reflecting taxonomic differences, more than 300 species representing 58 genera were listed by Anton Meyer (1932–33) in his monograph on the group, and many significant contributions have appeared in the literature since that date.

The proboscis, a hook covered introvert, is the most distinctive organ in the Acanthocephala. Its form and the arrangement of its hooks reflect specific and generic differences more readily than any other single structure, yet previously no attempt has been made to present an analysis of the tendencies toward diversification in the arrangement of the probos-

cis hooks. Of the many diverse types of proboscis which have been described, each has been treated as a specific entity, as though it were a thing in itself without genetic relationships to other patterns. However, much of the evolution of the group is clearly reflected in the diversification of the proboscis and its armature.

In a limited extent, taxonomists have acknowledged this fact, for hook arrangement has always been considered as of great significance in taxonomic descriptions. Diverse systems for designating hook arrangements have been devised in the more than two centuries that these worms have been studied. Some of these systems have been discarded and from time to time other systems have been proposed. Rarely have the suggested schemes been based on any realization of evolutionary changes modifying a simple basic pattern into the diverse expressions of present day forms.

The degree of consistency in pattern of arrangement and in numbers of proboscis hooks is not fixed in equal degree in the various species of Acanthocephala. In some species, individual variation is practically unknown, while in others there are wide limits to the number of hooks as well as to their arrangement on the proboscis. Since the hooks are laid down in definitive form and number early in larval life and usually, within reasonable limits, the form and relations remain constant throughout the life of the individual, the taxonomic characters provided by the hooks reveal few growth changes. Within relatively close limits number, form, and size seem to be controlled in practically all species by the hereditary mechanism and can not be subject to direct influence by other factors.

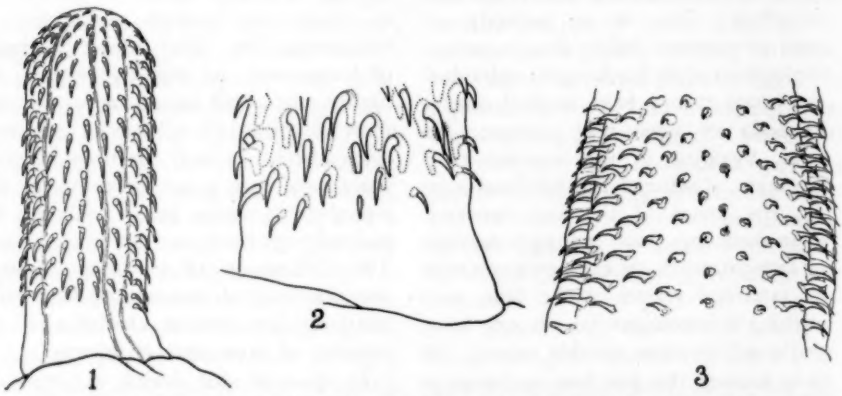
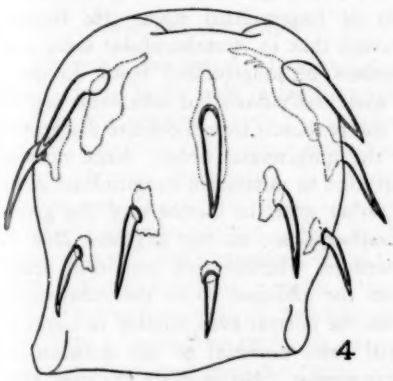



FIG. 1. PROBOSCIS OF ACANTHOCEPHALUS DIRUS SHOWING TYPICAL, QUINCUNXIAL ARRANGEMENT OF THE HOOKS WITH LITTLE REGIONAL DIFFERENTIATION (After Van Cleave)
FIG. 2. BASE OF THE PROBOSCIS OF ACANTHOCEPHALUS RANAE SHOWING ABNORMAL HOOK ARRANGEMENT ACCOMPANYING THE OCCURRENCE OF AN ODD NUMBER OF LONGITUDINAL ROWS OF HOOKS (After Lühe, 1912)
FIG. 3. BASAL REGION OF A PROBOSCIS OF CENTRORHYNCHUS SHOWING DISINTEGRATION OF PATTERN OF ARRANGEMENT INVOLVING ONE HOOK OF COMPLETELY REVERSED ORIENTATION

In its most generalized form (Figs. 1 and 4) the proboscis is provided with hooks that are arranged in radial symmetry, with the apex of the proboscis as the center from which regularly ordered rows radiate. Alternating check rows form a pattern that has been commonly referred to as "quincunxial" arrangement. The form of the proboscis is so regular and the pattern of its hooks is so specifically constant in these examples of radial

symmetry that there is little challenge to analyze the monotonous pattern. But even in a proboscis showing radial symmetry not all of the hooks are of identical form and size. There is very commonly progressive axial change in form and size of hooks at the two extremities of the proboscis. Here they are usually more slender and less sharply recurved than in the mid-region. The exact pattern of axial graduation is often distinctive for all members of a species. From this slight axial differentiation as a start, some of series of both longitudinal and cross rows, but these rows are alternating in staggered fashion (Fig. 1) so that the members of alternating cross rows fall into the same longitudinal rows and *vice versa*. This geometric arrangement makes it convenient in the study of whole mounts to follow diagonal lines of hooks in counting the longitudinal rows visible on one lateral face of the proboscis. In the writings of nineteenth century workers there is still confusion in the interpretation of their descriptions, whether they were



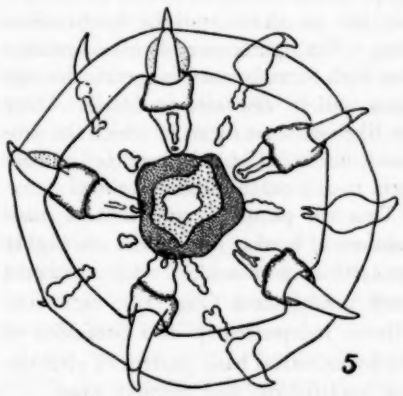




FIG. 4. PROBOSCIS OF NEOECHINORHYNCHUS CRASSUS IN SIDE VIEW. (Redrawn from Lynch, 1936)
Example of a simple proboscis with only three circles of hooks
FIG. 5. END VIEW OF AN ABNORMAL PROBOSCIS OF NEOECHINORHYNCHUS VENUSTUS HAVING FIVE INSTEAD OF THE NORMAL SIX HOOKS TO EACH CIRCLE (Redrawn from Lynch, 1936)

the most conspicuous zonal specializations have their origin as shown in forms like *Corynosoma* (Fig. 9) and *Centrorhynchus* and *Mediorhynchus* (Figs. 12 and 13).

In attempting to analyze the factors that might be responsible for perfect radial symmetry, either a single factor or a perfectly integrated series of factors might be invoked, for other than the axial graduation in size there is no clue to any mechanism whereby the extremes of regional diversification in some species might have their origin.

In the familiar quincunxial order the proboscis hooks may be viewed as parallel recording the number of alternating circles of hooks or the number of hooks in each longitudinal row. The number of circles is twice the number of hooks in one longitudinal row, plus or minus one, for often adjacent vertical rows differ by one hook. Among present day morphologists it is very generally the practice to express the formula of proboscis hooks in number of longitudinal rows and number of hooks in each row, indicating the observed range of variability in both counts. However, in some very primitive forms, such as the Neoechinorhynchidae (Figs. 4 and 5), hook designation must be by

circles because the proboscis is so short that characteristically only three circles are present. If this pattern were described in terms of longitudinal rows, alternating "longitudinal" series consist of two and one hook respectively. A similar condition wherein regimentation of the hooks conforms to circular rows only, will be discussed later. Examples will be cited from among the highly specialized Archiacanthocephala, particularly those living in mammalian hosts. In some members of this group (Fig. 18), the proboscis hooks fall readily into circles but fail to show straight longitudinal lines. The significance of this in connection with formulae used in specific descriptions will be discussed in detail. There are likewise some forms in which the proboscis hooks, at least in part, fail to conform to any exact pattern of rows.

Thus the primitive condition of small numbers of hooks (Fig. 4) and the highly specialized proboscides with distorted hook arrangement (Fig. 23), each contributes independently to a confusion of the hypothetical basic pattern of alternating longitudinal and circular rows.

Departures from a fixed hook pattern of radial symmetry fall into two distinct classes which for convenience may be grouped as teratological variations and normal variations. The latter comprise two distinguishable types, intra-specific variability in absolute numbers of hooks often evident among individuals of many species, and regional diversification which finds its chief expression in the development of asymmetry of form and size of the hooks in various regions of the same proboscis. These last named conditions provide the avenues along which evolutionary tendencies are clearly marked and often reveal evidences of specific, generic, or even greater taxonomic distinctions.

### TERATOLOGICAL VARIATIONS

Orderliness in hook arrangement is so distinctive among the Acanthocephala that evidences of disorganized interruptions in the regular pattern and random scattering of supernumerary hooks stand out in bold contrast to the usual. Lühe (1912) in his analysis of variability in hook arrangement on the proboscis of *Acanthocephalus ranae* (Fig. 2) was one of the early writers to call specific attention to irregularities in pattern. He pointed to the fact that perfect quincunxial order is based on a system involving even numbers of longitudinal rows. He further showed that in *Acanthocephalus ranae* odd numbers of longitudinal rows do exist in some individuals but here some region of the proboscis suffers definite disruption of the quincunxial order. Since normal variation in number of longitudinal rows is rather great in members of the genus *Acanthocephalus*, no one has been able to determine whether this condition arises from the addition to or the subtraction from the normal even number of longitudinal rows essential to the quincunxial arrangement. No analysis has ever been able to demonstrate any regularity for the position of "seams" in proboscides possessing odd numbers of longitudinal rows.

Such anomalies suggest that the unity in plan of construction of the proboscis is not perfect, for though the pattern of the proboscis ornamentation is predetermined in the developing embryo this pattern may become disrupted by introduction of a zone of nonconformity into the usual pattern.

A second type of teratological variation is one in which the normal hook pattern becomes confused by the addition of irregularly scattered hooks not conforming to the usual rows. Such instances have been found in relative frequence (Fig. 3) among species of the genus *Centrorhynchus*.

That these are abnormal or supernumerary hooks is borne out by the fact that often they point in random direction without reference to the orientation of the normal hooks. The significance of these hooks of chaotic arrangement is not clear. They give evidence that the normal, integrated pattern is subject to individual modification that is not affected by environmental factors but must reside in the developing embryo. They thus give a basis for understanding the asymmetry of the highly specialized proboscides discussed in the following section.

### NORMAL VARIATIONS

*Intraspecific variability.* The extent of fidelity in hook formula is far from constant in the various groups of Acanthocephala. In some of the more generalized genera, normal variability is wholly lacking and only injury or teratological variations are encountered. Such is the case in many of the representatives of the order Eoacanthocephala. Lynch (1936) examined one specimen of *Neoechinorhynchus* (Fig. 5) with the proboscis in end view and determined that there were only five hooks in each circle. Except for a few teratological instances mentioned in the literature three circles of six hooks each are so rigidly predetermined in the genus *Neoechinorhynchus* that individuals with eight (genus *Octospinifer*) or with twelve hooks to a circle (genus *Gracilisentis*) are not only specifically distinct but have other morphological features which substantiate their recognition as unquestionably valid genera. On the other hand, wide individual ranges of hook numbers are regularly encountered in many genera, especially in the two major groups Palaeacanthocephala and Archiacanthocephala. Among these plastic forms, females tend to have more rows of hooks than males of the same species and though all direct available evidence supports the view that hook number is predetermined in the acanthella larval stage there have been some authors who have maintained that relative size of the adult worms may be correlated with number of rows of hooks independently of the sexual differences mentioned above. Thus Baylis (1927: 42) observed that in *Polyacanthorhynchus* "the number and size of the hooks also appear to increase with age of the specimen." Such conditions are extremely rare in the Acanthocephala and deserve critical restudy. Lühe (1912) in his analysis of conditions in *Acanthocephalus ranae* was one of the first to give direct attention to variability in the hook rows within a species. He found in *A. ranae* extremes of 12 and 20 longitudinal rows of proboscis hooks. The range of variability has never been tested as a possible genetic factor because of unsurmountable difficulties arising from the complicated life cycle, as well as the fact that no means of culturing these worms has ever been perfected.

Every evidence points to a genetic control of the number of hooks on the proboscis with the range of possible variability variously fixed for different species. Out of the individual variability which this control permits, in many species differentiation very commonly proceeds toward establishing groups of individuals clustered around common modes and from these groups polymorphic species give rise to new varieties and ultimately to distinct species. Often clearly defined species, differing but slightly in other characters, are readily distinguishable on the basis of distinctly different hook formulae. Conversely, identical hook formulae may be found in distinct species readily differentiated on the basis of other morphological characters. In some instances identical proboscides on different

bodies are but the result of convergence while in other instances they seem to represent the results of speciation within an older polymorphic stock.

At one extreme, hook formulae become so rigidly fixed that only relative size of hooks supports other morphological means of differentiating species. At the other extreme, wide degree of individual variability in hook pattern provides material from which polymorphic species may become fragmented into distinct groups recognizable as either subspecies or as separate species.

*Regional diversification.* While perfect radial symmetry is considered as the most generalized form of hook arrangement, there are numerous factors which may disturb it. The significance of the different types of asymmetry will be discussed with particular reference to evolutionary diversifications and to application as systems for designating hook arrangement in taxonomic descriptions. For convenience of discussion these will be classed under four heads, each of which will be treated and examples cited.

1. Dorso-ventral asymmetry, specializations affecting one or more entire longitudinal rows of hooks.

2. Focal asymmetry, affecting segments of individual rows of hooks or of groups of rows.

3. Zonal asymmetry, reflected particularly in division of the proboscis into anterior and posterior zones with different hook types but also shown in the specialization of other regions of the proboscis.

4. Longitudinal condensation, whereby adjacent circles become fused.

1. Dorso-ventral asymmetry.—In cylindrical proboscides, it is not uncommon for the hooks on the ventral surface of the proboscis to be somewhat larger or at least stronger than those on the dorsal. Teleologically, this seems explainable on the ground that with the proboscis setting at an angle to the body proper the ventral hooks serve effectively for preventing the proboscis from being pulled from its anchorage through the force of the peristaltic action of the host intestine. This teleological explanation has little merit if the operation of natural selection were offered as the means of accomplishing dorso-ventral diversification for the hooks are fully formed and perfected in the larva before becoming functional. Some inheritable factor for diversification divorced from the influence of function in the mature worms seems to be indicated in postulating any mechanism whereby dorso-ventral specialization proceeds. Orthogenesis is the avenue of evolution most directly available for diversification of the proboscis hooks when natural selection and use seem to be incapable of operation.

All degrees of dorso-ventral asymmetry are encountered, ranging from slight diversification of the two surfaces as in some species of *Rhadinorhynchus* to complete diversification as expressed in *Aspersentis* (Fig. 6) where the two surfaces are wholly unlike in form and size of the hooks and those on the dorsal show strong tendency toward disintegration of the regular plan of orientation.

Though less spectacular than conditions found in *Aspersentis*, by far the most significant instances of dorso-ventral asymmetry have come to light only recently among the members of the family Rhadinorhynchidae. Members of this family have long been choice examples of simple difference in weight and form of the hooks on dorsal and ventral surfaces of the proboscis but in *Filisoma bucerium* the hooks of the median dorsal row (Fig. 7) are specialized as blunt, horn-shaped structures though all the adjacent rows have sharp-pointed hooks.

2. Focal asymmetry.—Focal asymmetry is highly localized as well exemplified in forms such as *Arhythmorhynchus frassoni* (Fig. 8) and *Corynosoma turbidum* (Fig. 9). In these species a few enormous hooks on the ventral surface of the proboscis are wholly out of keeping with the proportions of adjacent hooks. They occupy and dominate such wide areas of the proboscis surface that the entire plan of organization of the proboscis is disturbed and rows are skewed in the regions adjacent to the enlarged hooks. In the A parallel though different condition maintains in *Illiosentis* (Fig. 11), where a continuous circle of hooks at the base of proboscis has a few enlarged ventral hooks.

Dorso-ventral asymmetry is expressed often and in varying degrees. The hooks are laid down in early life in the invertebrate host before functional activity of grappling organs could operate to emphasize or suppress one surface over another. Nor could functional activity of surrounding parts influence the relative

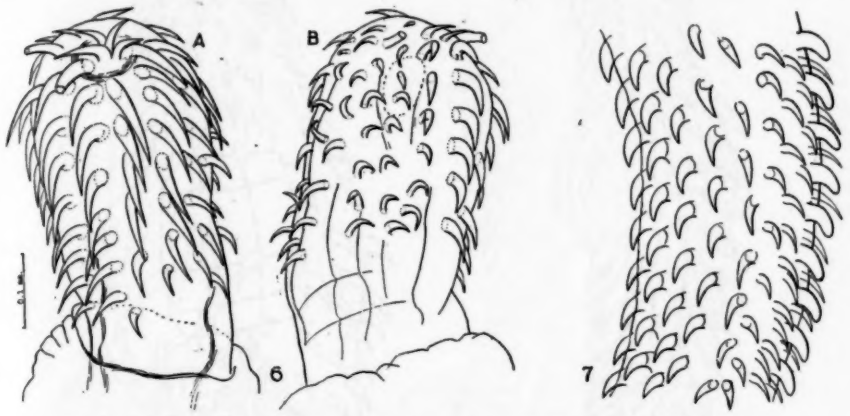



FIG. 6. PROBOSCIS OF ASPERSENTIS SHOWING EXTREME OF DORSO-VENTRAL DIFFERENTIATION
A. ventral surface. B. dorsal surface of the same proboscis (after Van Cleave)
FIG. 7. SEGMENT OF PROBOSCIS OF FILISOMA BUCERIUM SHOWING DIFFERENTIATION OF THE MEDIAN DORSAL ROW OF HEAVY, BLUNT, HORN-LIKE HOOKS (After Van Cleave)

drawing of *C. turbidum* (Fig. 9), lines connecting the hooks on the ventral surface in the region of the focal asymmetry show how spacing of rows is disturbed by the dominating presence of the enlarged hooks though actual number of hooks is not altered.

Another type of focal asymmetry is characteristic of some species of *Rhadinorhynchus*, as for instance in *R. tenuicornis* (Fig. 10), which possesses a conspicuous crescent of hooks at the base of the proboscis on the ventral surface only, not a portion of a continuous basal circle. development of hooks. This makes it seem obvious that control of dorso-ventral asymmetry must be through the herditary mechanism. As such it may function in sharply focused action affecting but a single row of hooks in *Filisoma bucerium*, in broader influence affecting several rows of hooks to the exclusion of others or in very broad influence marking complete dorso-ventral differentiation as in *Aspersentis*.

3. Zonal asymmetry:—Zonal asymmetry represents an extension of the disturbances characteristic of focal asym-

metry to the involvement of sectors of adjacent rows. This is most often expressed in specialization of basal portions of the proboscis and contrary to the teleological explanation offered for differentiation of the ventral hooks, zonal specialization is more often restricted to the dorsal surface of the proboscis except in those instances where the entire base of the proboscis is involved.

In sharp contrast to those forms which show slight progressive diminution in size of hooks toward the proximal end of the proboscis (Fig. 1) stand those which have sharp differentiation of the proboscis into two clearly defined zones with characteristic hook types on each. The clearest examples are found in *Centrorhynchus* (Fig. 12) and *Mediorhynchus* (Fig. 13) in which the anterior region is provided with hooks having prominent recurved roots while the basal region is clothed with simple, thorn-like hooks. In the two instances mentioned, the line of differentiation is fairly clearly marked by the line of insertion of the receptacle near the middle of the proboscis. That this morphological set-up is associated with the sharp differentiation of the hooks is further supported by the fact that in *Gigantorhynchus* the receptacle is inserted near the anterior tip of the proboscis and in this genus a single anterior crown of hooks is followed proximally by a

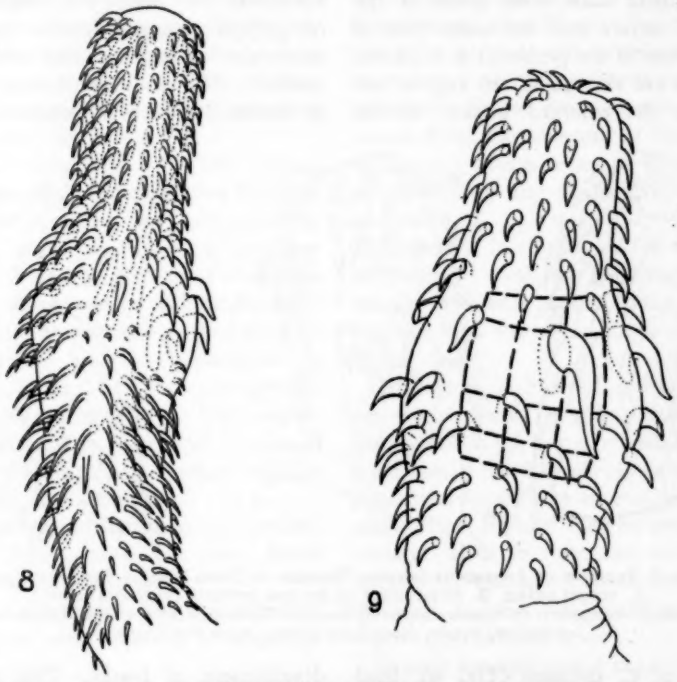



FIG. 8. ARHYTHMORHYNCHUS FRASONI, PROBOSCIS SHOWING DISTINCTIVELY ENLARGED HOOKS ON THE MIDDLE OF THE VENTRAL SURFACE (After Lühe, 1911)

FIG. 9. CORYNOSOMA TURBIDUM, PROBOSCIS SHOWING ENLARGED VENTRAL HOOKS
Broken lines show how the symmetry in spacing of the hook rows has been disturbed (After Van Cleave)

long series of spine-like hooks of more simple form.

One instance in which radical zonation at the base of the proboscis is divorced from the location of the line of attachment of the receptacle (Fig. 14) is in the species *Corynosoma semerme*, which has several circles of diminutive hooks posterior to the enlarged anterior region of the proboscis with its effective attachment mechanism. The small hooks here seem explainable as reduplication of the characteristic circle of small hooks which so often occurs at the base of the proboscis (see Fig. 1). Some growth or genetic factor operates toward the duplication of parts.

The most striking instances which depend upon some specific, highly localized influence have been but recently discovered. In the genus *Illiosentis* (Van Cleave and Lincicome, 1939) the four dorsal rows at the base of the proboscis (Fig. 11) show striking modifications from adjacent areas. The hooks differ in form and size from those in adjacent lateral rows and from those anterior to them in the same longitudinal rows. In even more striking manner, *Tegorhynchus pectinarius* shows profound specialization (Fig. 15) in its four dorsal rows. While all the hooks at the base of the proboscis are modified as a fairly closely set comb-like structure at the base of each row, the region anterior to the comb in the four dorsal rows becomes conspicuously modified. Immediately anterior to the comb,

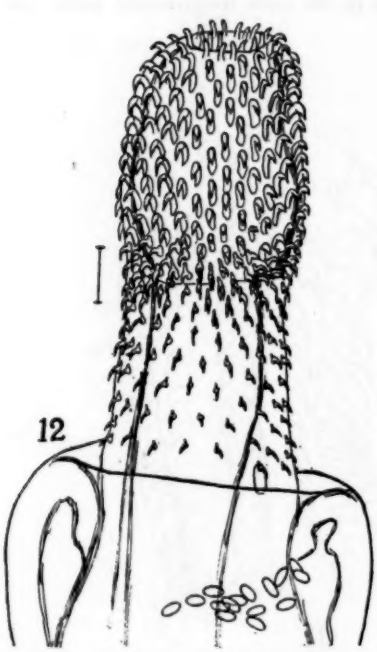
10

11

FIG. 10. RHADINORHYNCHUS TENUICORNIS ANTERIOR END OF BODY AND BASE OF THE PROBOSCIS ILLUSTRATING FOCAL ASYMMETRY IN THE DEVELOPMENT OF A VENTRAL CRESCENT OF HOOKS NOT ASSOCIATED WITH THE BASAL CIRCLE OF PROBOSCIS HOOKS (After Chandler)

FIG. 11. ILLIOSENTIS FURCATUS, BASAL REGION OF PROBOSCIS SHOWING SPECIALIZATION OF VENTRAL HOOKS IN THE BASAL CIRCLE TO FORM A CONSPICUOUS CRESCENT OF HOOKS AND THE PECULIARLY MODIFIED HEAVY HOOKS ON THE DORSAL SURFACE (After Van Cleave and Lincicome)

there is an unusually stout hook with grotesquely enlarged root. Especially in two of the rows this anomaly seriously affects the development and pattern of the hooks anterior to the large rooted hook. In some instances, the adjacent hooks are vestigial; in others, apparently lacking. This center of influence is somewhat that region. Each papilla lying close to the line of hooks but in position between the basal and second hook imposes a slight degree of asymmetry upon the arrangement of the hooks for the basal hook becomes thrown out of line with the hooks in the same longitudinal row. The basal hook of the adjacent row is



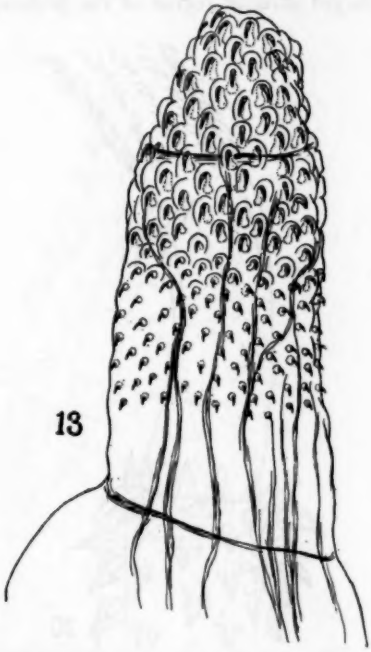




FIG. 12. PROBOSCIS OF CENTRORHYNCHUS ILLUSTRATING EXTREME DIFFERENTIATION OF HOOK TYPES OF ANTERIOR AND POSTERIOR REGIONS OF THE PROBOSCIS

FIG. 13. PROBOSCIS OF MEDIORHYNCHUS SHOWING HEAVY, ROOTED HOOKS ANTERIOR TO INSERTION OF THE RECEPTACLE AND SIMPLE THORN-LIKE HOOKS POSTERIOR TO THE INSERTION

analogous to the ventral modifications associated with enlarged hooks in *Arhythmorhynchus* and *Corynosoma* though the results are more profound in the dorsal modifications of *Illiosentis*.

In *Gorgorhynchus clavatus* the presence of a pair of small lateral papillae, which seem to be sensory in function, near the base of the proboscis disrupts the perfect arrangement of the proboscis hooks in likewise skewed from its normal position. In fact, for two rows on either side of a papilla the hooks are disturbed in their arrangement.

4. Lontitudinal condensation.—Among the conditions where quincunxial order is most clearly violated (Fig. *16*) are those in species showing one or more circles with twice the normal number of hooks. Expressed in terms of longi-

tudinal rows the proboscis is described as conforming to a usual hook formula, the proboscis there occur one or more circles of twice the usual number of hooks.

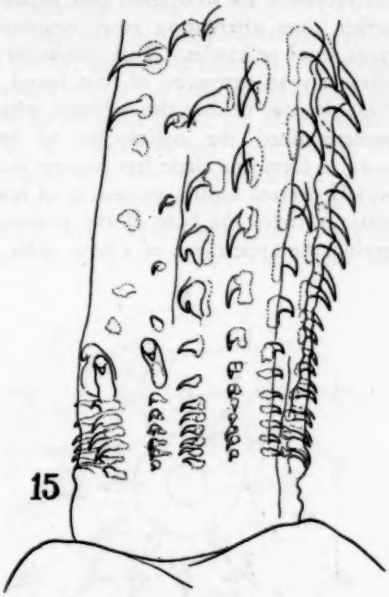



FIG. 14. CORYNOSOMA SEMERME PROBOSCIS, SOMEWHAT DIAGRAMMATIZED TO ILLUSTRATE THE ANTERO-POSTERIOR DIFFERENTIATION OF HOOKS IN THE SAME LONGITUDINAL ROW (After Forssell)

FIG. 15. TEGORHYNCHUS PECTINARIUS BASAL REGION OF PROBOSCIS SHOWING COMPLICATED ZONAL DIFFERENTIATION, PARTICULARLY EVIDENT IN THE DORSAL ROWS (After Van Cleave, 1940)

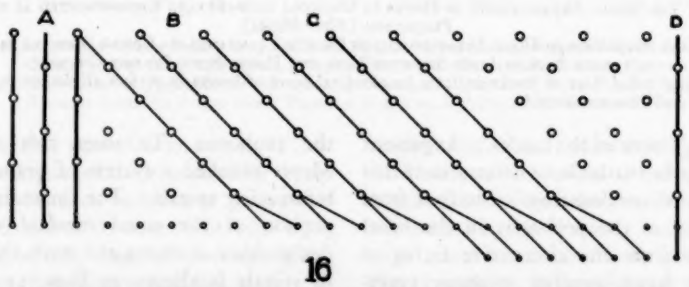


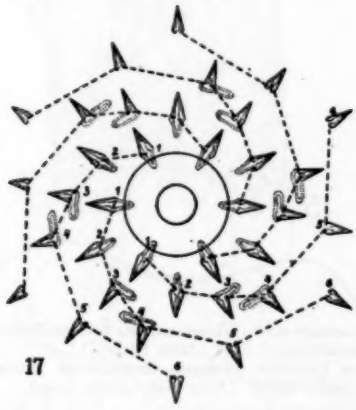

FIG. 16. ORIGINAL DIAGRAM ILLUSTRATING DIFFERENT METHODS OF DESCRIBING HOOK ARRANGEMENT
In the first three vertical lines (A) two adjacent transverse rows at the base of the series have been fused, destroying the quincunxial order, though the hooks all conform to longitudinal rows. (B) diagonal rows necessitate the introduction of bifurcation into the pattern which becomes even more evident in (C) where several adjacent transverse rows have fused. In (D) designation as a longitudinal row avoids the necessity of introducing the complicated system of bifurcating spirals.

stating the number of longitudinal rows with the number of hooks in each, then mentioning the fact that at the base of Such instances are encountered in *Nipporhynchus* and other Gorgorhynchidae and often in the Archiacanthocephala.

In *Illiosentis* (Fig. 11) and *Tegorhynchus* (Fig. 15), adjacent rows at the base of the proboscis are so ordered that adjacent rather than alternating rows constitute cross rows or circles. This condition is obviously an extension of that found in *Nipporhynchus* in that the influence which predetermined the coalescence of two rows to form one circle has become more widely exerted until a succession of fused rows encircles the base of the proboscis giving the appearance of a new order in the arrangement of the hooks. At present no avenue is available to determine if this longitudinal condensation is derived from shortening of the proboscis in the basal region or from the alternative factor of increased hook number without corresponding increase in length of the proboscis itself.

In the simplest condition, where but two adjoining circles at the base of the proboscis become fused, the relationship of the members of this basal circle to the longitudinal rows on the remainder of the proboscis is clear, as shown in Fig. 16. However, initial fusion is the starting point of an increasing complexity which leads to complicated systems for designating hook patterns such as the one devised by Meyer. As stated above, when the hooks in *Nipporhynchus* are considered as disposed in longitudinal and circular rows, they conform readily to specification, but when the hooks are counted in diagonal, spiral rows (Fig. 16, B) those of the basal circle fail to conform with the spirals clearly evident on the remainder of the proboscis. To meet this dilemma Meyer invoked a system of branching or bifurcating spirals. The immediate comparison of the usual method of hook designation as contrasted with the system of spirals is shown in Figs. 21 and 23. When several circles at the proboscis base become fused and crowded the interpretation of arrangement becomes progressively more difficult by any manner of designation of rows, except when longitudinal condensation resulting from fusion of circles is implied.

In a relatively simple proboscis, as for



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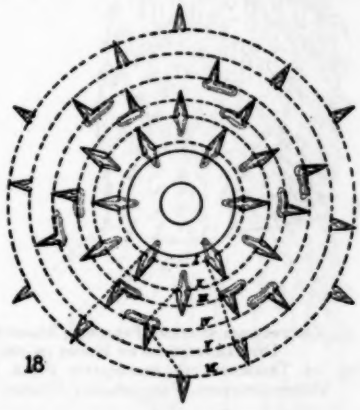

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FIG. 17. THE SPIRAL ARRANGEMENT OF HOOKS IN ONCICOLA CAMPANULATA RECONSTRUCTED AS A POLAR PROJECTION (After Meyer)

FIG. 18. POLAR PROJECTION OF HOOK ARRANGEMENT IN ONCICOLA CAMPANULATA COPIED DIRECTLY FROM MEYER BUT WITH BROKEN LINES SHOWING HOW THE HOOKS FORM PERFECT CIRCLES

Alternating radial lines of hooks indicate longitudinal rows of hooks in perfect alignment but between these the radial lines are skewed.

example, *Oncicola campanulata*, Meyer resorts to polar projection (Fig. 17) to explain his system of hook designation. Fig. 19 shows Meyer's interpretation of the hook order in *O. campanulata*. In Fig. 18 the same projected pattern is reduced to the more usual system of designation by longitudinal and cross rows or circles. In this instance half of the longitudinal rows are practically perfect in alignment (see Figs. 18 and 20) while in intervening longitudinal rows the arrangement the hooks are arranged on a spheroidal surface so that meridians show as arcs, not as straight lines.

In analyzing a more complicated system of hooks, such as is found in *Pachysentis canicola*, Meyer has resorted to reconstruction in his polar projection of the pattern (Fig. 21) which is not borne out in his drawing of a side view of the proboscis of this same species (Figs. 23 and 24). In Fig. 22, Meyer's projection is copied but his lines of bifurcating spirals are

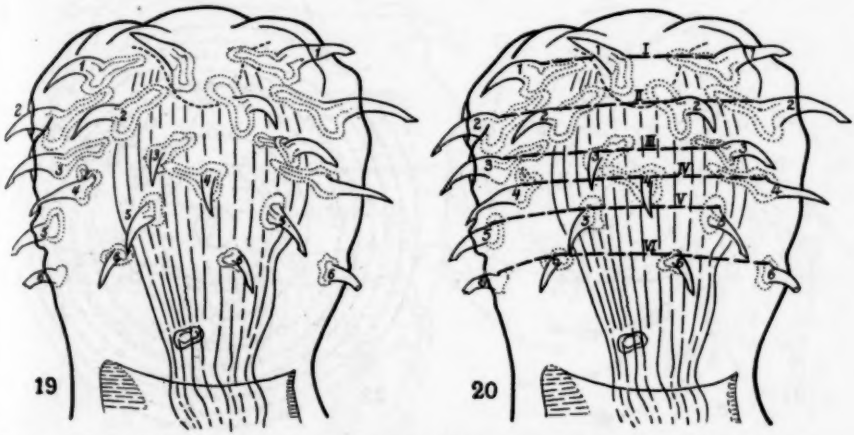
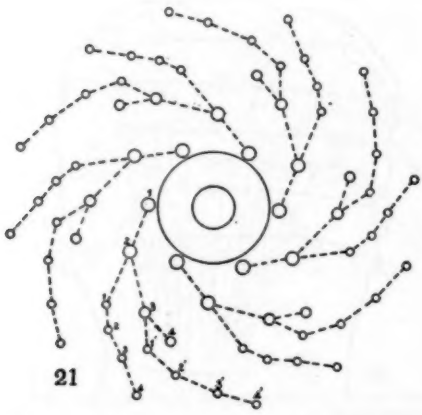



FIG. 19. LATERAL VIEW OF THE PROBOSCIS OF ONCICOLA CAMPANULATA, REDRAWN FROM MEYER, SHOWING WITH BROKEN LINES HOW THE HOOK PATTERN FALLS INTO PERFECT TRANSVERSE ROWS
FIG. 20. LATERAL VIEW OF PROBOSCIS OF ONCICOLA CAMPANULATA, REDRAWN FROM MEYER, SHOWING WITH BROKEN LINES HOW THE HOOK PATTERN FALLS INTO PERFECT TRANSVERSE ROWS

is considerably skewed from a straight line. Since polar projection is necessarily based on reconstruction, subjective interpretations are bound to enter. In Fig. 19 is presented a side view of *O. campanulata*, as drawn by Meyer and on which he based his polar reconstruction (Fig. 17). The same drawing is represented in Fig. 20 with the conventional method for designating hook arrangement. It is obvious that not all the longitudinal rows are in perfectly straight lines (see Fig. 18) but at least to some extent the skewing of the lines is attributable to the fact that omitted and in their place it is shown that the hooks, as he has spaced them, conform to 9 circles of which the 5 apical rings and one other contain 6 hooks each, while 3 rings contain 12 hooks in each circle. This confusion is consequent upon the union of adjacent circles as mentioned for *Nipporhynchus* earlier in this same section, except that in *Pachysentis* crowding at the base of the proboscis involves nine of the primitively twelve circles of hooks. Direct evidences of the dual nature of the fused circles is not equally clear in all of the coalesced rings. Thus

(Fig. 22) circles IV and V come near to fusion but since their component hooks show differences in size and in development of the root the two circles are readily segregated. In the reconstruction of hook arrangements shown in Fig. 22, circles VI, VII and IX represent fusion of two circles each while circle VIII stands in primitively simple form, unconfused by union with adjacent circles on the crowded part of the proboscis. However, in this interpretation Meyer is not consistent with his drawing of a lateral view of the same proboscis (Fig. 23) for here cross lines have been added to Meyer's Fig. 260a to show how the hooks conform to circular arrangement before subjected to diagrammatic presentation. In this drawing of the proboscis (Fig. 23) nine circles are obvious as in the reconstructed diagram (Fig. 22) but the details regarding components of the circles do not harmonize. In Fig. 23, circles VII, VIII, and IX are coalesced rings while at the apex of the proboscis all the circles retain primitive simplicity. Accepting Meyer's Fig. 260a (which is here reproduced as Fig. 23) without any questions as to the validity of his observations, circle VII is obviously composed of hooks ordered in two levels upon the proboscis. This duplicity is even more clearly shown in the hooks of ring IX where hooks 1, 3, 5, and 7 stand anterior to the series 2, 4, and 6. Here is definite evidence that the proboscis of *Pachysentis canicola* contains primitively a pattern of seventy-two hooks ordered in twelve circles of six each. By longitudinal condensation in the region of the basal portion of the proboscis six primitive circles become condensed into three. The bizarre system of bifurcating spirals invoked by Meyer rests in large measure on subjective bias in rearranging the hooks when the pattern is transposed to polar projection. Though in this instance the hooks are arranged in perfect circles they do not show alignment in consistent longitudinal rows. Since the attempt to express hook formula in either longitudi-



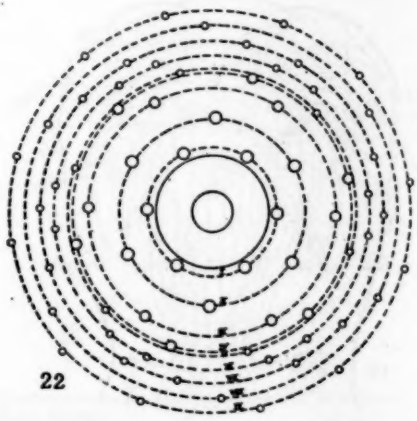




FIG. 21. POLAR PROJECTION OF HOOK ARRANGEMENT IN PACHYSENTIS CANICOLA SHOWING IN RECONSTRUCTION MEYER'S INTERPRETATION OF HOOKS ARRANGED AS BIFURCATING SPIRALS (After Meyer)
FIG. 22. POLAR PROJECTION OF HOOK ARRANGEMENT IN PACHYSENTIS CANICOLA COPIED DIRECTLY FROM MEYER, WITH CONCENTRIC CIRCLES TO REPLACE HIS BIFURCATING SPIRALS
Comparing this figure with Fig. 23, a serious error in his reconstruction is evident

nal or spiral rows necessitates reconstruction and this of necessity involves subjective error it is best to refer to the hook arrangement in proboscides of this type in terms of circles only.

## CONCLUSIONS

In its most generalized form, the acanthocephalan proboscis displays a relatively static specific uniformity in size and arrangement of its hooks. For example, among the Neoechinorhynchidae and many of the Echinorhynchidae form and pattern are fixed to such a degree as to suggest that a single set of relatively simple genetic factors might operate to produce characteristics having little diversification and relatively small amplitude of variability. Among these forms, which exhibit varying degrees of radial symmetry, the quincunxial pattern is most often observed. Characteristically, this pattern is most easily reduced to an expression of longitudinal rows of hooks and the most available formula consists in citing the number of longitudinal rows with limits of numbers of hooks in each. In very short proboscides, the circles furnish the most characteristic basis for description of hook pattern.

The fusion of adjacent circles of hooks at the base of the proboscis offers no obstacle to expression of hook pattern in terms of either longitudinal rows or circles. The introduction of an artificial system of bifurcating spiral rows of hooks as a means of describing the hook pattern fails to give recognition to the fact that crowded adjacent circles become fused, thus modifying the primitive condition of hooks arranged as perfect check rows.

Some proboscides have hooks so irregularly arranged that no system of perfect rows can be designated.

Even among the generalized forms, instances of conspicuous departure from

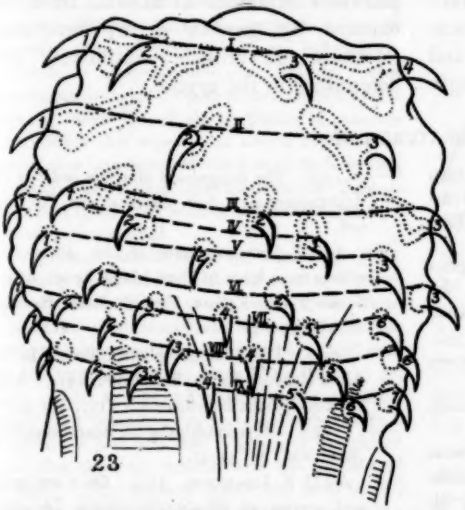


FIG. 23. PACHYSENTIS CANICOLA, SIDE VIEW OF PROBOSCIS (After Meyer, 1932) BUT WITH BROKEN CROSS LINES ADDED TO SHOW HOW THE HOOKS FALL INTO TRANSVERSE ROWS (OR CIRCLES)
Crowding of circles at the base of the proboscis has resulted in adjacent circles becoming fused
FIG. 24. DETAIL OF HOOK ARRANGEMENT IN P. CANICOLA TO ILLUSTRATE MULTIPLE BIFURCATION OF SPIRAL ROWS (From Meyer)

the normal are not uncommon, but among the more highly specialized forms of the Acanthocephala the proboscis is dynamic and highly plastic within the family and genus, though relatively consistent within the individual species. Species differ widely in the extent to which individual variability expresses itself. The proboscis shows not only wide amplitude of individual variability and incidence of abnormality but even more strikingly inherent specific tendencies toward regional specialization and development of zonal asymmetry. Both circular and longitudinal rows of hooks may singly or in limited groups express inherent tendencies toward specialization, while within individual rows strikingly constant form differences have become established in a diversification which involves both focal and zonal asymmetry.

This dynamic concept suggests that the mechanism for hereditary control is much more highly elaborated than has been previously supposed. The form and pattern of arrangement of the hooks on the proboscis represent a mosaic, little influenced by growth or by functional relations and probably intimately predetermined in the zygote.

## LITERATURE LIST


Baylis, H. A. 1927. Some parasitic worms from *Arapaima gigas* (Teleostean fish) with a description of *Philometra senticosa* n. sp. (Filarioidea). *Parasitol.*, 19 (1): 35–57.

Chandler, A. C. 1934. A revision of the genus *Rhadinorhynchus* (Acanthocephala) with descriptions of new genera and species. *Parasitol.*, 26 (3): 352–358.

Lühe, M. 1911. Acanthocephalen. Die Süsswasserfauna Deutschlands, Heft 16. *Jena.*

——. 1912. Zur Kenntnis der Acanthocephalen. *Zool. Jahrb.*, Suppl. 15, 1 Bd.: 271–306.

Lynch, J. E. 1936. New species of *Neoechinorhynchus* from the western sucker, *Catostomus macrocheilus* Girard. *Trans. Amer. Micros. Soc.*, 55 (1): 21–43.

Meyer, A. 1932–3. Acanthocephala. Bronn's Klassen u. Ordnungen des Tierreichs, Bd. 4, Abt. 2, Buch 2, *Leipzig.*

Van Cleave, H. J. 1929. A new genus and new species of Acanthocephala from the Antarctic. *Ann. and Mag. Nat. Hist.*, Ser. 10, vol. 1: 229–231.

——. 1936. The recognition of a new order in the Acanthocephala. *Jour. Parasitol.*, 22 (2): 202–206.

——. 1937. Acanthocephala of the genus *Corynosoma* from birds of Dyer Island, South Africa. *Göteborgs Kgl. Vetensk. Vitterh. -Samh. Handlig.*, Ser. B, 5: 1–6.

——. 1940. The Acanthocephala collected by the Allan Hancock Pacific Expedition, 1934. Allan Hancock Pacific Expeditions, 2 (15): 499–527.

——. 1940b. Relationships of the Acanthocephala. *Amer. Nat.*, 75: 31–47.

——, and D. R. Lincicome. 1939. On a new genus and species of Rhadinorhynchidae (Acanthocephala). *Parasitol. (Cambridge)*, 31 (4): 413–416.

——, and L. H. Townsend. 1936. On the assignment of *Echinorhynchus dirus* to the genus *Acanthocephalus*. *Proc. Helminthol. Soc. Washington*, 3: 63.

# RESPIRATION IN THE LIVING CELL

By P. S. TANG

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PREFATORY NOTE

The following review article was sent from the depths of warring China in November, 1939. I have undertaken the friendly office of preparing it for publication, but without making any essential alterations or additions. That the literature references, especially those of recent years, are incompletely reviewed, is understandable—our Chinese friends have repeatedly asked for help in the form of scientific journals. Some idea of the conditions of existence under which this review, and several experimental papers, came into being are indicated in the following quotation from a letter received from Dr. Tang at about that time. The flame of scientific adventure is not easily extinguished.

"There was established in the interior of China, Kweiyang, a medical school for the training of physicians who are to be sent to the front. I was offered to be on the scientific staff, and be responsible for the preclinical courses, and to establish labs. This I took up, and went through all kinds of hardships to get there. . . . Six months in Kweiyang to start a medical school from nothing—absolutely nothing, except a 'hospital' of *four* beds, and a group of determined men. But those six months were the happiest of my life. . . . The medical school has been in full swing for over a year, with four terms a year with a good staff, and now a hospital of over 100 beds, and laboratories which may well compare with any school in China in equipment. And if there is anything more satisfactory to a pioneer, the furniture, and the laboratory benches of that school are a source of joy to me, even when I am away from them. I designed everything from a three-legged stool (after the principle of the tripod, for the floors are uneven) to the actually hand-made pneumothorax machine which was rigged up from parts gotten from junk-shops all by myself, in order that a very serious case of tuberculosis may be treated. And since then, that machine, crude as it may be, has served over 200 patients.

I went to Hongkong for two months to buy equipment for the college, and in doing so, I travelled all over the southwest of China on bus, pushing the bus most of the time, and sometimes in the dark, when no lights were available, I had two hand-torches in my hands, and ran before the bus so that we could reach the city for the night."

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*University of Chicago*

A NUMBER of reviews have appeared recently on the subject of cellular respiration from the standpoint of enzyme chemistry (Meldrum, 1934; Barron, 1939; Elvehjem and Williams, 1939). We shall consider in this account the respiration of the living cell in relation to its environment. The subject under review is well defined, dealing with cells suspended in an aqueous medium, with or without added metabolite, and in an atmosphere containing oxygen; as this system responds to varying experimental conditions. The relations between the respiratory activity of the living cell and the environmental factors will when possible be expressed in formal terms lending themselves to theoretical interpretation. Only the literature relevant to this phase of cellular respiration is discussed.

## INTENSITY OF RESPIRATION

The rate of respiration of a cell is changed with the state of development, the amount and kind of metabolites supplied, the nature and extent of cell surface, and the enzyme systems contained in the cell. It is obvious that, since each cell respires as a separate unit, the amount

of gas exchanged in a given time is proportional to the number of cells present; but the intensity of respiration, whether expressed in terms of number of cells or of unit weight, is of little value except for comparing like cells with respect to the variation of a particular factor, such as temperature. A few numerical values for the rates of respiration of unicellular organisms are given here to illustrate the point. Expressed in terms of cmm. of oxygen consumed per million cells per hour, *Chlorella pyrenoidosa* respires at the rate of 0.012 at 15°. This value is doubled on addition of excess glucose (Tang and French, 1933). The rate for eggs of *Arbacia punctulata*, expressed in the same units, is 33.6 at 25°, and is raised to 160 on fertilization (Tang, 1931; Tang and Gerard, 1932). The latter value is also that of *Asterias* eggs (Tang, 1931a), fertilized or unfertilized. Uniformity in rates of respiration ($Q$) is not improved by expressing them in terms of the gas exchanged per unit dry weight, nor per unit surface area. Although the rate of respiration for unfertilized *Arbacia* eggs is comparable with that for *Asterias* eggs, when both are expressed per unit surface, the rate of the fertilized *Arbacia* eggs is decidedly too high compared to that of the *Asterias* eggs (Tang, 1931). The table given by Specht (1934) contains further data illustrating lack of uniformity in the values of $Q$.

### INFLUENCE OF THE KIND OF SUBSTRATE

A living cell placed in an aqueous medium without added metabolite will respire for some time at a constant rate until the foodstuff within the cell is depleted, when the rate declines. If compounds such as glucose or pyruvate are added to the solution at this time, the rate of respiration is usually greatly accelerated. However, not all organic compounds are oxidized, and not all the oxidizable compounds are utilized to the same extent by the cells. There is a species specificity in the utilization of metabolites. Specificity between the organism and substrate has been tabulated for bacteria by Stephenson (1939, p. 189 *et seq.*), and Harden (1932) states that yeast will ferment glucose, fructose, mannose, and galactose. Many synthetic stereoisomers of these sugars are unfermentable, as are the corresponding pentoses, tetroses, and the alcohols.

Johnson (1936) recently made some interesting observations on the utilization of carbohydrates by two species of luminous bacteria, *Vibro phosphorescens* and *Achromobacter Fischeri*. He showed that these species differ not only in the kind of carbohydrate utilized, but also in the rates at which the utilizable ones are oxidized. Thus, of the simple alcohols and sugars, both species oxidized only the compounds with three or six carbon atoms, and *A. Fischeri* was further limited to the reducing compounds, except for glycerol and malicitose. Further, inhibition of oxidation occurred when two substances were simultaneously supplied to *A. Fischeri*. For example, $\alpha$ methylglucoside, though exerting no apparent influence on the oxidation of glucose, completely inhibited the oxidation of other hexoses, and retarded the oxidation of glycerol; and mannose and galactose were slightly inhibited by lyxose, the former to a greater extent than the latter. Except for the methylglucoside, mannoketoheptose was the only compound which retarded the oxidation of fructose; it also exerted the greatest retardation on mannose, galactose, and glycerol. Johnson interprets the phenomena of inhibition in terms of competition for a common adsorption surface capable of causing breakdown of the inhibited compound.

Confirming the work of Genevois (1927) and of Emerson (1927), Tang (1937) found that galactose, glucose, fructose, mannose, and maltose accelerate the rate of respiration by *Chlorella pyrenoidosa*, while lactose and sucrose do not. Of the sugars utilized, mannose is the least readily oxidized; the others accelerate the sugar-free respiration two to three times. Potassium pyruvate is readily oxidized at pH 5.4 or above, while sodium lactate at M/10 inhibits reversibly both oxygen consumption and carbon dioxide production.

The ability of a strain of yeast, *S. wanching*, to utilize different organic compounds was studied by Tang and Lin (1937). Among the substances oxidized with ease are glucose, fructose, mannose, maltose, lactose, sucrose, galactose, pyruvate, acetate, and lactate. Xylose, arabinose, and glycerol are oxidized with difficulty, if at all. Galactose, lactose, xylose, and arabinose are fermented with difficulty; while pyruvate, sucrose, maltose, mannose, fructose, and glucose are fermented with ease. Glycerol, lactate, and acetate are not utilized anaerobically, while formate, propionate, butyrate, valeriate, succinate, oxalate, and citrate are neither oxidized nor fermented. The respiratory quotient is unity for yeast suspended in M/15 $KH_2PO_4$ with M/10 K-acetate or Na-lactate. It is 1.2 for cells suspended in M/15 $KH_2PO_4$ with M/10 K-pyruvate (Tang and Wu, 1938).

The value of such studies lies in the clue they may give to the nature of the enzyme systems in the cells and the relative affinities with which these enzyme systems combine with the substrates; for, other things being equal, the intensity of respiration probably increases directly with the affinity with which enzyme systems combine with the substrates. Such studies may also help to elucidate the mode of action between enzyme systems and substrates, through absorption or competitive adsorption. And finally, the intermediate steps in the oxidation of the more complex compounds may be inferred from the feeding of simpler compounds to the cells. One method, used in the past to study the intermediate steps in carbohydrate breakdown, is to feed the cells with compounds which are presumptive intermediates. If the rate of respiration is sufficiently accelerated by the added substance, it may be an intermediate. This method has an advantage over other methods, in that the cells are maintained under physiological conditions; but the results thus obtained need confirmation by methods involving the isolation and identification of the compounds.

### INFLUENCE OF SUBSTRATE CONCENTRATION

French, Kohn and Tang (1934) found that the rate of respiration of *Chlorella* cells, suspended in the dark in Knop solution without added substrate, declined with time in a manner which may be described by the equation for a first order chemical reaction until about the twentieth hour (varying according to temperature) when the rate approached a constant low level. They interpreted the results in terms of the oxidation of two different substances. This is supported by the existence of two different respiratory quotients, that of the declining phase of respiration being 1.0, while that of the constant phase is 0.65. The two phases of respiration also have different temperature characteristics.

Stier and Stannard (1936) studied a yeast, *S. Cerevisiae*, suspended in a sugar-free phosphate solution, and analyzed kinetically the rate of respiration. Confirming French, Kohn and Tang (1934) and Geiger-Huber (1934), they observed

an early declining rate of respiration, closely following the course of a first order chemical reaction, which gradually came to a constant level.

The equation for a first order chemical reaction is:

$$\frac{dx}{dt} = k(a - x) \qquad (1)$$

in which $a$ is the initial concentration of the reactant, $x$ is the amount of the reactant transformed in $t$ minutes, and $k$ is a constant.

In the case of cellular respiration, the substrate concentrations $x$ and $a$ are usually not subject to direct measurement, and the amount of oxygen consumed is taken to be a measure of them. If we assume that the amount of oxygen consumed is proportional to substrate concentration, then $a$ is proportional to the total oxygen consumed, $A$, from beginning to end of the experiment; $x$ is proportional to $y$, the oxygen consumed in $t$; and the rate of respiration, $Q$, is a first order function of $A - y$:

$$Q = f\left(\frac{dx}{dt}\right) = k'(a - x)$$

$$= k''(A - y). \qquad (2)$$

The constant $k''$ is of the nature of a velocity constant, but may include other unknown terms. When $a$ is present in excess and $x$ is negligible compared to $a$, (2) may be written:

$$Q = k''A = k''' \qquad (3)$$

and the order of reaction becomes zero, with a constant rate independent of substrate concentration.

When utilizable foodstuffs are added to the suspension of cells, respiration is accelerated to an extent depending on the amount of substrate. Ordinarily, an excess is added so that the rate of respiration is independent of substrate concentration, but with small quantities the effect of concentration on respiration is apparent. Rubenstein (1932) added to *Sarcina lutea*, suspended in Sorensen phosphate buffers, glucose, lactate, pyruvate, and acetate, and followed respiration until the accelerating effects were over. The curve of respiration was found to follow the above equation and the apparent velocity constants were calculated. At 37°C., the constant for glucose oxidation was 0.38 in the irradiated series, and 0.41 in the dark series. At 20°, it was 0.12 in the light, 0.10 in the dark. The constants at 20° for acetate oxidation and for glucose oxidation were alike. The total oxygen consumed was only two-thirds of that required for the complete oxidation of the added metabolite.

Geiger-Huber (1934) observed, in yeast cells without added metabolite, a declining rate of respiration which came to a low and constant level after four hours. Addition of glucose accelerated the rate. Between M/10,000 and M/500, the rate of oxygen uptake was proportional to glucose concentration in the external medium, in accord with equation (2). Between M/100 and M/650, the rate was independent of glucose concentration, conforming to equation (3). Between these two limits was a range of transition. The data did not closely follow the equation of Michaelis and Menten (1913), based on a theory of substrate-enzyme complex formation. Similar experiments by Johnson (1936) on luminous bacteria, yielded data which do not lend themselves to quantitative treatment. Confirming Cook and Stephenson (1928) and Rubenstein (1932), Johnson observed that the added metabolite is only oxidized two-thirds to completion. The equation of Michaelis and Menten may be written:

$$K = (E)(S)/(ES)$$

and, assuming the rate of enzyme reaction, $v$, is proportional to $(ES)$, it gives:

$$v = \frac{V(S)}{K + S}. \qquad (4)$$

In these equations, $v$ is the velocity of the enzyme reaction, $(S)$ is the concentration of substrate, $(E)$ is the concentration of enzyme, and $K$ is a constant. $V$ is the maximal velocity of the enzyme reaction, obtained when $E$ exists completely in the form of $ES$, the enzyme-substrate complex, the concentration of which is $(ES)$. $(ES) + (E)$ is kept constant throughout the course of reaction, but $(S)$ is varied. Equation (4) is identical in form with that for the Langmuir (1932) adsorption isotherm.

Equation (4) is the expression for the velocity of a reversible bimolecular reaction with the total concentration of one reactant kept constant. The numerical value of $K$, the dissociation constant of the enzyme-substrate complex is given by the substrate concentration at half-maximum velocity, where $(E) = (ES)$. Assuming that the observed rate of respiration is proportional to the amount of enzyme-substrate present, Burk and Lineweaver (1934) applied the equation to N-fixing bacteria. It successfully describes the change in rate of respiration with changing substrate concentration.

We may conclude that, when the course of respiration follows a first order reaction, the concentration of substrate is probably the limiting factor, and that the apparent velocity constant is characteristic for the critical substrate being oxidized. When the equation for a rectangular hyperbola, as in (4), is followed, the interpretation may be of two kinds: either respiration is limited by the enzyme-substrate complex, the rate measures the concentration of this complex, and the constant is its dissociation constant; or rate of respiration measures the amount of metabolite adsorbed. At present, we have no way of distinguishing between these interpretations; probably both processes are involved.

It may be noted that the constant low level of respiration of starved cells is of significance to their economy. It represents a steady state, perhaps of the transformation of an otherwise unoxidizable substance into one that is readily used. It also represents a balance between the expenditure of energy needed for maintenance of a living organism and the conservation of the available stored foodstuff.

### INFLUENCE OF HYDROGEN ION CONCENTRATION

Few accounts deal with the effect of hydrogen ion concentration on cell respiration. Rubenstein (1932) found, on varying pH 1.4 to 12, that the optimum range for the respiration of *Sarcine lutea* is 5.8 to 8. More complete observations, on yeast cells, were made by Tang (1936) and Tang and Wu (1938). With phosphate buffers, there is little change in the rate of respiration between pH 5.3 and pH 7, but it falls off beyond pH 8, to zero at pH 12. In phthalate buffers, no respiration is measurable at pH 2.2 and 2.6, and is very low at pH 3. Between 3 and 3.6 there is a steep rise, and the maximum rate at 3.6 is maintained up to pH 6.2. Within the range of pH overlap, the rate of respiration of the yeast cells is alike in both buffers, and the maximum rates are equal.

In acetate buffer, however, even in an overlapping pH range, the influence of hydrogen ion concentration is markedly different. Respiration falls steeply from the maximum at 5.8 to zero at 4.2, in a logarithmic manner expressed by:

$$\frac{d \ln Q}{d\,\mathrm{pH}} = K = 0.87. \qquad (5)$$

This relationship between $Q$ and pH strongly suggests hydrogen ions as the cause for the inhibition of respiration, but the failure of other buffer solutions, such as pyruvate and lactate, at the same pH range, to exert any apparent effect on yeast respiration, points to the contrary. The effect cannot be attributed to the acetate ions, since the latter are known to accelerate yeast respiration, and since no relation was found to exist between $Q$ and the concentration of the acetate ions. Free acetic acid was thought to be the natural possible agent for the effect but, when the data were analyzed, the only relation found was an approximate linear relation between $1/Q$ and $(HA)$, the concentration of the free acid:

$$1/Q = k(HA) + C,$$

when $Q$ is expressed in percentage, and $(HA)$ in normality, $k$ is of the order of 38,000, and $C = 0.002$. This suggests that the respiration of yeast cells is probably inhibited by free acetic acid molecules, their concentration within the cells being a function of that in the external solution (Gutstein, 1932). The inhibitory effects of 2,4-dinitrophenol (at high concentrations) on yeast (Krahl and Clowes, 1938b) and of lactates on *Chlorella* (Tang, 1937) follow a similar relation.

In borate buffer the behavior is markedly different. The rate falls from pH 6.6 to a minimum at pH 7.2, then rises again to a plateau between pH 8 and 11. This peculiar behavior in borate was traced to the formation of complex molecules between borate and glucose, which alters both the optical properties and the pH of the borate-glucose solution (Tang, 1936a). Respiration in veronal buffer does not differ significantly from that in phosphate. Oxygen consumption by yeast cells in lactate buffer is independent of pH between 3.5 and 5.5, and the rate is only half of that in phosphate with glucose at 5.8. Addition of glucose doubles the rate at the lower pH, but is less effective at the higher one. Respiration in solutions buffered with pyruvate proceeds at the same rate as in glucose-phosphate or glucose-lactate solutions, and little affected by either pH or glucose.

Evidently, the nature of the buffer used markedly influences the effect of pH on the rate of a physiological process. Different buffer anions and molecules, at the same pH range, may affect respiration differently. In the case of the phosphate and phthalate buffers, the effect of pH on respiration is very similar to the effect of pH on enzyme activity, and may be interpreted in terms of a change in the dissociation constant of the enzyme-substrate union (Haldane, 1930, p. 23). From acetate buffers free acetic acid molecules seem to penetrate the yeast cells to cause inhibition. In borate buffers, pH evidently influences the activity of glucose and its union with borate, and so the ease with which it is oxidized. Other possible effects of pH include, alteration of adsorption processes in the cell, killing of cells by hydrogen or hydroxyl ions, and change in permeability of the cell membrane to metabolites.

### INFLUENCE OF TEMPERATURE

One general characteristic of all life processes is that temperature profoundly influences their rates. Within the physiological range (usually from above freezing to 40°) the relation between temperature and rate is described by certain mathematical expressions (Belehradek, 1935). The Arrhenius equation has been used extensively, especially by Crozier (1924) and his co-workers, and will be used here as an empirical tool convenient for description. Despite the incomplete

theoretical basis for application of the equation to biological processes (cf. Burton, 1936; Snyder, 1931), the temperature characteristic, $\mu$, serves well to describe the behavior of cells towards temperature. Table 1 gives the temperature characteristics ($\mu$) for respiration of a number of cells.

For temperatures below about 20°, the most frequently observed temperature characteristics for cell respiration are 12,000, 19,000, and 21,000, approximately.

TABLE 1

*Temperature characteristics for oxygen consumption and $CO_2$ production by unicellular organisms*

| SPECIES | TEMP. RANGE | CRITICAL TEMP. | TEMP. CHARACTERISTICS LOWER TEMP. | | HIGHER TEMP. | AUTHOR |
|---|---|---|---|---|---|---|
| *Chlorella pyrenoidosa* | | | | | | |
| (In glucose) | 1°–27° | — | | 19,000 | | Crozier, Tang and French |
| (No glucose, initial phase) | 0.6°–18° | 11.5° | 19,500 | | 3,500 | French, Kohn and Tang |
| (No glucose, steady state) | 0.6°–18° | — | | 5,600 | | |
| Yeast | | | | | | |
| O-consumption | 3°–35° | 15.7°, 29° | 19,530 | 12,440 | 8,290 | Stier |
| $CO_2$-production | 5°–40° | 22.5° | 22,200 | | 12,250 | Slator |
| *Arbacia* eggs | | | | | | |
| Cytolyzed | 11°–30° | — | | 7,200 | | Rubenstein and Gerard |
| Fertilized | 11°–30° | 22° | 10,800 | | 6,500 | |
| Resting | 11°–30° | — | | 12,500 | | |
| *Azotobacter* | 20°–30° | — | | 19,330 | | Lineweaver, Burk and Horner |

### INFLUENCE OF OXYGEN TENSION

In a normal atmosphere (air), respiration of cells proceeds undiminished when other conditions are not changed. This constant rate may be maintained even when the oxygen tension in the surrounding medium is decreased to a fraction of that in air. For this reason it has often been said that cellular respiration is independent of the oxygen tension in the surrounding medium. The effect of oxygen tension on the rate of respiration in tissues and lower organisms has been reviewed by Gerard (1931a) and by Tang (1933). When oxygen tension is much reduced, respiration varies with oxygen tension in the following manner:

$$Q = \frac{Q_0 KP}{1 + KP} \qquad (6)$$

in which $Q$ is the rate of respiration at any tension $P$, $Q_0$ is the maximum rate of respiration at the higher oxygen tensions when $Q$ is independent of $P$, and $K$ is a constant characteristic of each species of

The facts, that these values have been associated with hydrogen and hydroxyl ion and with iron catalysis, and that many of the temperature characteristics for enzyme activities may be associated with these values, led Crozier (1924) to suggest that $\mu$ indicates the nature of the master reaction limiting the rate of biological oxidation. Should this hypothesis be proved to be theoretically correct, an extensive study of the temperature characteristics will be very valuable.

cells and of the particular set of experimental conditions used. Tang and French (1933) studied the rate of respiration of *Chlorella* as a function of temperature and of oxygen tension and found equation (6) to apply. $K$ changes with temperature as does the equilibrium constant of chemical reactions (that is, the Van't Hoff reaction isochore holds) according to:

$$\frac{d \ln K}{dt} = \frac{\Delta H}{RT^2} \qquad (7)$$

The term $\Delta H$ is a constant, and $T$ is in absolute units.

Assuming that the rate of respiration is limited by, and is a measure of, the amount of oxygen or metabolites adsorbed on cell surfaces, equation (6) may be identified with the adsorption isotherm of Langmuir (1932) (see Gerard, 1931a). The identical equation has been derived by Warburg and Kubowitz (1929), however, from assumed complex formation between oxygen and enzyme. The derivation follows:

Using the terminology of Warburg and Kubowitz (1929);

$C_{FeO}$ = concentration of enzyme-oxygen complex (FeO)

$C_{Fe}$ = concentration of respiration enzyme (Fe)

$C_{\Sigma Fe} = C_{Fe} + C_{FeO}$

$P_o = P$ = oxygen tension in atmospheres

$B$ = velocity constant for Fe oxidation

$Z$ = velocity constant of reduction of FeO through spontaneous dissociation

$Z'$ = velocity constant of reduction of FeO through respiration

$A = Q$ = rate of respiration.

In the reaction:

$$Fe + O = FeO$$

when saturated with substrate, and at stationary state,

$$\frac{-dC_{Fe}}{dt} = Bp_0C_{Fe} - (Z + Z')C_{FeO} = 0.$$

When $Z \gg Z'$,

$$Bp_0C_{Fe} = Z'C_{FeO}. \qquad (8)$$

Letting $A$ = rate of respiration at $P_o$ and $A_o$ = maximum rate (at which $C_{Fe} = C_{\Sigma Fe}$), then at any $A$, the concentration of Fe as a fraction of $\Sigma$Fe is given by:

$$C_{FeO} = \frac{A}{A_0}C_{\Sigma Fe}, \qquad (9)$$

$$C_{Fe} = C_{\Sigma Fe} - C_{FeO} = \left(1 - \frac{A}{A_0}\right)C_{\Sigma Fe}$$

$$= C_{\Sigma Fe} - \frac{A}{A_0}C_{\Sigma Fe}$$

$$= \left(1 - \frac{A}{A_0}\right)C_{\Sigma Fe}. \qquad (10)$$

Substituting (9) and (10) into (8), and letting $n = \frac{A}{A_o}$, and $\frac{B}{Z'} = K$, gives:

$$\frac{n}{(1-n)p_0} = \frac{B}{Z'} = K.$$

From which

$$n = \frac{P_0K}{1 + K_{p_0}},$$

or

$$A = \frac{A_0K_{p_0}}{1 + K_{p_0}}$$

and, since $P_0 = P$, $A = Q$, and $A_0 = Q_0$

$$Q = \frac{Q_0KP}{1 + KP}$$

which is identical with (6) above.

It is clear then that the hyperbolic relationship existing between the rate of respiration and oxygen tension does not alone distinguish between interpretations in terms of adsorption or of chemical union

of the enzyme with oxygen. Viewed as enzyme-oxygen complex formation, the constant $K$ becomes a dissociation constant for the formation and dissociation of the complex; viewed as adsorption, $K$ is the equilibrium constant for condensation and evaporation of oxygen from cell surfaces.

The problem of oxygen diffusion into cells as a limiting factor in respiration has been treated mathematically by Gerard (1931a). His analysis has been further generalized by Rashevsky (1938) and his colleagues in a series of papers, but only a few results (Landahl, 1937) can be given here.

Assume, for the idealized spherical cell with a coefficient of diffusion, $D$, a permeability to oxygen, $b$, and a constant rate of glucose breakdown, $k$: (1) that glucose breaks down to lactic acid at a rate proportional to its own concentration, (2) that lactic acid resynthesizes to glucose at a rate proportional to the square of its own concentration, and (3) that lactic acid is oxidized at a rate proportional to its own concentration and to that of oxygen. Derived equations then permit the calculation of $D$, $b$, and $k$.

The data of Amberson (1928), of Shoup (1929), of Tang (1931), and of Tang and Gerard (1932) were analyzed by the use of these equations, and were found to fit the theoretical curves very closely. The values of the constants for *Arbacia* eggs and for luminous bacteria are given below:

*Arbacia eggs, fertilized*

Data of Amberson (18°–20°)
$D \gtrsim 3 \times 10^{-5}$ cm²/min.
$b > 3 \times 10^{-2}$ cm/min.
$k \sim 1.5 \times 10^{-5}$ gm/cc/min.
Data of Tang and Gerard (25°)
$D \gtrsim 0.6 \times 10^{-5}$ cm²/min.
$b > 0.8 \times 10^{-2}$ cm/min.
$k \sim 10^{-5}$ gm/cc/min.

*Arbacia eggs, unfertilized*

Data of Tang (25°)
$D \gtrsim 1.4 \times 10^{-5}$ cm²/min.
$b > 0.7 \times 10^{-2}$ cm/min.
$k \sim 0.3 \times 10^{-5}$ gm/cc/min.

*Luminous bacteria*

Data of Shoup (21°)
$D \gtrsim 4 \times 10^{-5}$ cm²/min.
$b > 2$ cm/min.
$k \sim 2 \times 10^{-2}$ gm/cc/min.

Although these experimental data fit the theoretical considerations very well, certain important deviations in the organisms need explanation. The constants for fertilized eggs obtained by Amberson are many times higher than those obtained by Tang and Gerard; and the temperature difference in the experiments, only about five degrees, should not significantly alter the physical constants $D$ and $b$. Some physical processes have a high temperature coefficient, as the permeability to water of *Arbacia* eggs (McCutcheon and Lucké, 1932), but even so the constants should be higher for the data of Tang and Gerard, which were obtained at the higher temperature. The changes in $D$ and in $b$ on fertilization are of different direction or magnitude, depending on which data are used for comparison. These discrepancies are hard to explain on the basis of the analyses of Rashevsky and his coworkers.

## INFLUENCE OF PHYSICAL AGENTS

The effect of hypertonic balanced solutions on echinoderm egg respiration was studied by Warburg (1930), by Loeb and Wasteneys (1913), and by Runnström (1930). The first two investigations showed that hypertonic solution increases the rate of respiration of unfertilized sea urchin eggs to the value of fertilized ones; and Runnström found the same for

hypotonic solutions. Whether hypertonic solutions increase the respiration of the fertilized eggs is still not certain. The respiration observed under these conditions is not that of intact eggs, but that of their cytolyzed fragments. Rubenstein (1932) studied the effect of NaCl on the respiration of *S. lutea*, from zero to five molar concentration of the salt, and found a wide optimum range between 0.1 N and about 1.8 N. Even this wide variation in osmotic pressure produced no cytolysis or other visible cell changes. Bodine (1934), studying the development of grasshopper eggs, found that hypertonic solutions caused dehydration of the cells and a drop in respiration. This was more or less reversible, depending on the length of exposure and strength of the solution with which the eggs were treated. Bodine and Boell (1936) reported that ultracentrifuging produced a marked reduction of respiration of actively developing grasshopper eggs and embryos, but not of the blocked or diapause embryos.

Irradiation of *S. lutea* with visible light increases the rate of oxygen consumption at temperatures below 30°, but decreases it at 35°, with low substrate concentration (Rubenstein, 1932). The value of the temperature characteristic for the respiration of *S. lutea* is altered by irradiation. Tang and Lin (1936) observed that the potentials at a platinum electrode placed in a suspension of *Chlorella* cells differed in light and in darkness.

Tang (1936b) found that ultraviolet light decreased the respiration of yeast, the logarithm of the percentage of respiration at any exposure being a linear function of its duration. The slope of the line is independent of temperature from 10° to 22°C. The general equation expressing the survival ratio of unicellular organisms as a function of the duration of exposure to harmful agents such as X- and ultraviolet-radiations is:

$$N = N_0 e^{-QPt}\left(1 + QPt + \frac{\overline{QPt}^2}{2!} + \frac{\overline{QPt}^3}{3!} \cdots + \frac{\overline{QPt}^{(n-1)}}{(n-1)!}\right), \quad (11)$$

in which $N$ is the number of cells surviving after irradiation for a duration $t$ (in this case, $N$ is proportional to the amount of oxygen consumed in $t$); $P$ is the probability of a quantum of radiation being effective; $Q$ is the rate of absorption of radiant energy by the cells; $e$ is the base of natural logarithms; and $N_0$ is the original number of respiring cells present (in this case, the respiration of unirradiated cells). The term $n$ may be interpreted in two ways. If (11) is derived on the assumption that the cell is killed (and stops respiring) when a definite number of molecules is inactivated (Rahn 1934), then $n$ represents this number. If derived on the assumption that a successive number of "quantum-hits" (Crowther, 1926; Swann and del Rosario, 1932) are necessary to kill (and stop respiration), then $n$ represents the number of "quantum-hits." When $n$ is unity, (11) becomes:

$$N = N_0 e^{-QPt}$$

$$\log (N/N_0) = -QPt = -\lambda t \quad (12)$$

The constant $\lambda$ determined by the experiment is 0.11 at 10° or 22°, so that the $Q_{10}$ for the process is unity.

### INFLUENCE OF CHEMICAL AGENTS OTHER THAN METABOLITES

The respiration of sea urchin eggs is intensified by OH-ions, and by traces of Cu, Ag, and Au, as well as by Fe compounds (Warburg, 1930). Mast *et al.* (1936) showed that sulphur accelerated the respiration of *Chilomonas*. Heavy water was found to retard the respiration

of luminous bacteria (Harvey and Taylor, 1934) and of *Chlorella* (Craig and Trelease, 1937), though to a less extent than its photosynthesis.

The action of electrolytes on the respiration of *Chlorella* was studied by Shibata (1929) who found that cells in distilled water consumed more oxygen than did those in Knop solution and that the rate is depressed as single salts are increased in concentration. The depressing action of the salts is in the order: K > Na > Li > Rb, and Sr < Mg < Ba < Ca. The antagonistic effects are:

For Ca: Rb < Na < K < Li
For Ba: Li < Rb < Na < K
For Mg: Rb < Li < Na < K
For Sr: Li < Rb < Na < K

Pirson observed more recently (1939) that deficiency of K ions causes an increase in the respiration of *Chlorella*, and this increase is reduced as much by Rb as by K, and more by C. Green *et al.* (1939) observed a reversible inhibition of both photosynthesis and respiration when *Chlorella* is treated with copper "poisons," such as thiourea and salicylaldoxime. The concentrations required are higher than those which inhibit photosynthesis. The ascorbic acid content was found to be 0.17 mg. per ml. of centrifuged cells.

Organic dyes affect the rate of respiration of cells in a manner proportional to the redox potentials of the dyes (De Meio *et al.*, 1935); and the addition of 2,4-dinitrophenol increases the respiration of sea urchin eggs (Field *et al.*, 1934, Clowes and Krahl, 1936), yeast (Plantefol, 1933, Field *et al.*, 1934), and luminous bacteria (Shoup and Kimler, 1934). Pratt and Williams (1939) recently found that pantothenic acid, liver extract, and thiamin accelerate yeast respiration.

The respiration of yeast and *Chlorella*, among others, is inhibited by CO, KCN and $H_2S$, (Emerson, 1927), but such cells as *Paramecium* and *S. lutea* (Gerard and Hyman, 1931; Gerard, 1931b; Rubenstein, 1932) are insensitive to these poisons. Narcotics such as vanillin, urethanes, diethylurea, phenylurea, propionitrile, and valeronitrile inhibit reversibly the respiration of erythrocytes (Warburg, 1928) and of *Azotobacter* (Lineweaver, 1933). Iodoacetate, although it inhibits the fermentation of yeast, has no effect on its respiration (Carol and Genvois, 1931).

Much use has been made of specific inhibitors and accelerators in the study of enzyme systems responsible for respiration, and the literature on this phase of cell respiration is very extensive. Since such studies are aimed primarily at the chemistry of the respiratory enzymes, they will not be dealt with here.

### INFLUENCE OF PHYSIOLOGICAL STATE

When unfertilized sea urchin eggs are cytolyzed, either by chemical agents or by mechanical means, the fragments respire as fast as the fertilized eggs, and the bulk of respiration is carried on by the nucleated portions (Warburg, 1915). The resting rate of intact unfertilized eggs is increased following fertilization, the factor of increase depending on temperature (Warburg, 1914; Warburg and Meyerhof, 1912; Tang, 1931; Rubenstein and Gerard, 1934). This effect is not found in *Asterias* eggs (Loeb and Wasteneys, 1912; Tang, 1931a). Respiration of fucus eggs is doubled upon fertilization, that of *Nereis* only slightly increased, and that of *Cummingia* and of *Chaetopterus* is even decreased (Whittaker, 1933).

A rhythmic production of $CO_2$ by fertilized eggs was reported by Lyon (1904) for *Arbacia punctulata*, and by Vles (1922) for *Strongylocentrotus*. Warburg (1915), Shearer (1922), and Gray (1925) failed to observe such a phenomenon in *Echinus* and *Strongylocentrotus*. The ques-

tion of a rhythmic variation in the respiration of fertilized echinoderm eggs is still not settled; for Warburg made observations at intervals too long to catch any rhythmic variations present, Gray made his runs at 10°, at which temperature respiration is too low to show any marked variation, and the data of Shearer do clearly indicate certain variations, despite his negative conclusion. When Shearer's results are plotted as rate of respiration, rather than total oxygen consumed, against time, a definite minimum is seen at the twenty-fifth minute after fertilization, when the fusion of the pronuclei occurs. The rate then gradually rises, reaching a maximum at the forty-fifth minute, and then falls to another minimum. Unfortunately, the experiment was discontinued at the sixtieth minute so that the respiration at the second cleavage was missed.

The physiological state of the cell is obviously an important factor in cellular respiration. Cells must remain intact if they are to continue to respire and their respiratory system to function properly. True, cytolyzed fragments may continue to respire, even at a higher rate than the intact cells in certain cases, but the phenomenon is only transitory, and sooner or later respiration ceases. That the nucleus is important as a locus of respiratory activity was shown by the work of Warburg, but that it is not the only center of respiratory activity is shown by the rather intense respiration of the pigmented granules in cell fragments. The recent work of Shapiro (1935), see below, also indicates that respiration is not limited to the nuclear region. The very interesting fact that the rate of respiration of different marine eggs may be accelerated, unaffected, or decreased, upon fertilization is another proof of the importance to respiration of the physiological state. That the physical state of marine eggs is altered upon fertilization is shown by their changed permeability (cf. McCutcheon and Lucke, 1933) and viscosity (Heilbrunn, 1928), and the formation of fertilization membranes. These considerations are significant in elucidating the site of oxidations in the cell.

### THE SITE OF OXIDATION

The question as to where in the cell oxidation takes place has long concerned physiologists. In a short note, Lillie (1902) reported that, when fresh alcoholic sections of frog tissue are treated with an alkaline solution of paradiamino-benzene and alpha naphthol, the nuclear region (especially the nuclear membrane) in the cells quickly turns blue, which suggests the nuclear surface is the site of oxidation. Osterhout (1917) reported that the colorless cells of the parasitic plant, *Monotropa*, turn dark by oxidation when exposed to air, and that the nuclear region is darkened most easily; again indicating that the nucleus is the site of cellular oxidation. Warburg's findings on cytolyzed cells and on nucleated and non-nucleated erythrocytes also support the hypothesis that the nucleus is responsible for the bulk of respiration in the cell. Shapiro (1935) fragmented fertilized and unfertilized *Arbacia* eggs, by high speed centrifuging, into nuclear and cytoplasmic regions and measured the respiration of the separated fragments. The unfertilized light halves, containing a nucleus but devoid of pigment, consumed oxygen at approximately the same rate as the whole cell; while the unfertilized pigmented halves, without a nucleus but possessing most of the yolk and echinochrome, displayed an oxygen-uptake 88 percent in excess of that of the whole egg. On fertilization, the light halves showed a 2.7 fold increase, similar to that shown by whole eggs, whereas the

pigmented halves did not significantly change their already high rate of respiration. These results indicate that the higher rate of respiration in the fertilized *Arbacia* eggs is primarily due to nuclear changes.

Runnström (1930) found that carbon monoxide, while barely diminishing the respiration of unfertilized sea urchin eggs, greatly increased that of the fertilized ones. Urethane actually increased resting respiration while diminishing that of fertilized eggs. On the basis of these experiments, Runnström suggested that a limited contact of respiratory enzymes with the substrate determined the reaction velocity of the resting eggs and that, consequently, considerable enzyme might be poisoned without decreasing the rate of oxidation. With these substances freed to react, by colloidal changes in active eggs, the inhibitors manifest their usual effects by combining with the enzyme. Rubenstein and Gerard, (1934) similarly interpreted their findings on the temperature coefficients of resting and fertilized eggs.

A series of experiments by Clowes and his associates (c.f. Krahl and Clowes, 1938a, 1938b), on the physiological effects of substituted phenols in relation to extra cellular and intra-cellular hydrogen ion concentration, is especially interesting and suggestive. Certain substituted phenols, notably those containing nitro- and halo-substituents in the benzene ring, reversibly block cell division and, in small concentrations, stimulate respiration, in higher concentrations, inhibit it. By using a series of such compounds, and by varying extra-cellular and intra-cellular pH, it was found that: (1) the substituted phenols penetrate the cells only in molecular form; (2) block of division is due to substituted phenol molecules in the cell; while (3) stimulation of respiration (at low concentrations) is due to substituted phenol anions in the cytoplasmic aqueous phase; (4) inhibition of respiration (above the optimum concentration) is due to substituted phenol molecules, as is the blocking of division.

The experiments of Wertheimer (1934), although not directly concerned with oxidation, throw light on the first process in the utilization of sugar by cells. Yeast takes up sugar in accord with the adsorption isotherm of Freundlich, indicating that the first step in sugar-uptake by the cells is an adsorption process.

It may be concluded that, although the nucleus may be a locus of intensive oxidation, the entire colloidal protoplasm of the cell is responsible for the process. The fact that respiration is governed in so many ways by the colloidal properties of protoplasm leads us to believe that the oxidation is intimately connected with the colloidal state of the cell. We may perhaps picture cellular respiration as a union between oxygen and metabolites through the mediation of respiratory enzymes, the entire process taking place only when proper surfaces are provided for the anchoring and activation of the three components. In other words, cellular oxidation involves reactions in a heterogeneous chemical system composed of oxygen, metabolites, enzyme-systems, and of specific surfaces provided by the colloidal protoplasm of the cell.

## CONCLUDING REMARKS

We have seen that the course of respiration in the living cell is influenced by many environmental factors, and the change of the respiratory activity with changing experimental conditions can be described by a number of formal relations. When certain assumptions are made, such as a proportionality between the respiratory rate and the amount of enzyme-

substrate present, the quantitative relations, describing the course of respiration may be identified with those describing the kinetics of enzyme and other reactions in homogeneous and heterogeneous chemical systems. Thus the course of respiration may be described by zero, first, or second order reactions; its changing rate with oxygen tension may be described in terms of the Langmuir adsorption isotherm or of the Warburg equation for enzyme-substrate complex formation; and the effect of temperature on respiratory rate may be described by Arrhenius' equation, and the change of constants with temperature by Van't Hoff's. The effect of ions on *Chlorella* respiration suggests ionic effects in colloidal systems, and the actions of poisons and of narcotics are quantitatively and specifically characteristic of chain reactions in pure chemical systems. The inhibition of respiration by ultraviolet radiation follows a logarithmic relation which may be interpreted according to the mass law in terms of the number of molecules inactivated.

As stated at the beginning, the purpose of this review is to examine the respiratory activity of the living cell from the standpoint of the kinetics of reactions in heterogeneous systems. When the relations between the rate of respiration and various experimental conditions are examined, it is found that they are adequately described by existing expressions used for the kinetics of homogeneous or for heterogeneous chemical reactions and of enzyme reactions. The theoretical implications of the identity of these formal relations must await further research, but they have at least established the generic continuity between respiration in the living cell and these physico-chemical processes.

Much of our knowledge concerning the mechanisms of chemical and enzyme reactions have come through studies on the kinetics of these reactions, and a study of the kinetics of cellular respiration may yield valuable information concerning the mechanism of the process, about which we still know very little.

## LITERATURE CITED


1. Amberson, W. R. 1928. The influence of oxygen tension upon the respiration of unicellular organisms. *Biol. Bull.* 55: 79–91.
2. Barron, E. S. Guzman. 1939. Cellular oxidation systems. *Physiol. Rev.* 19: 184–239.
3. Belehredak, J. 1935. Temperature and Living Matter. Borntraeger, *Berlin.*
4. Bodine, Joseph Hall. 1934. To what extent is developmental block dependent upon the metabolic activity of the embryonic cell? *Proc. Nat. Acad. Sci.* 20: 640–644.
5. Bodine, Joseph Hall, and Edgar John Boell. 1936. The effect of ultracentrifuging on the respiratory activity of developing and blocked embryonic cells (Orthoptera). *J. Cell. Comp. Physiol.* 7: 455–463.
6. Burton, Allan C. 1936. The basis of the principle of the master reaction in biology. *J. Cell. Comp. Physiol.* 9: 1–14.
7. Cayrol, MM. J. et L. Genevois. 1931. Inhibition spécifique de la fermentation alcoolique des cellules de levures sans arrêt ni de la respiration, ni de la réaction de Pasteur-Meyerhof, ni de la croissance. *Comptes Rendus Institut de France* 192: 1494–1496.
8. Clowes, G. H. A., and M. E. Krahl. 1936. Studies on cell metabolism and cell division. I. On the relation between molecular structures, chemical properties, and biological activities of the nitrophenols. *J. Gen. Physiol.* 20: 145–171.
9. Cook, R. P., and M. Stephenson. 1928. Bacterial oxidation by molecular oxygen. I. The aerobic oxidation of glucose and some of its fermentation products in its relation to the viability of the organisms. *Biochem. J.* 24: 1538–1550.
10. Craig, Francis N., and Sam F. Trelease. 1937. Photosynthesis of *Chlorella* in heavy water. *Amer. J. Bot.* 24: 232–242.
11. Crowther, J. A. 1926. The Action of X-Ray on *Colpidium colpoda*. *Proc. Roy. Soc. B.* 100: 390–404.

12. Crozier, W. J. 1924. On biological oxidations as a function of temperature. *J. Gen. Physiol.* 7: 189–216.
13. DeMeio, R. H., Milton Kisin, and E. S. Guzman Barron. 1935. Studies on biological oxidations. III. Mechanism of the catalytic effect of reversible dyes on cellular respiration. *J. Biol. Chem.* 107: 579–590.
14. Elvehjem, C. A., and P. W. Wilson [Editors]. 1939. Respiratory Enzymes. Burgess Pub. Co., *Minneapolis.*
15. Emerson, Robert. 1927. The effect of certain respiratory inhibitors on the respiration of *Chlorella*. *J. Gen. Physiol.* 10: 469–477.
16. Field, J., A. W. Martin, and S. M. Field. 1934. The effect of 2,4-dinitrophenol on the oxygen consumption of yeast. *J. Cell. Comp. Physiol.* 4: 405–420.
17. French, C. S., H. I. Kohn, and P. S. Tang. 1934. Temperature characteristics for the metabolism of *Chlorella*. II. The rate of respiration of cultures of *Chlorella pyrenoidosa* as a function of time and temperature. *J. Gen. Physiol.* 18: 193–207.
18. Gicgr-Huber, Max. 1934. Über den Einfluss der Konzentration des Atmungsmaterials auf die Atmungsgeschwindigkeit von Pflanzen. *Jahrb. wissensch. Bot.* 81: 1–34.
19. Genevois, L. 1927. Über Atmung und Gärung in grünen Pflanzen. *Biochem. Zeitschr.* 186: 461–473.
20. Gerard, R. W. 1931a. Oxygen diffusion into cells. *Biol. Bull.* 60: 245–268.
21. ——. 1931b. Observations on the metabolism of *Sarcina lutea*. II. *Biol. Bull.* 60: 227–241.
22. ——, and L. H. Hyman. 1931. The cyanide insensitivity of *Paramecium*. *Amer. Jour. Physiol.*, 97: 524–525.
23. Gray, J. 1925. The mechanism of cell division. Oxygen consumption during cleavage. *Proc. Camb. Phil. Soc. Biol. Sci.* 1: 225–236.
24. Green, Lowell F., James McCarthy, and C. C. King. 1939. Inhibition of respiration and photosynthesis in *Chlorella pyrenoidosa* by organic compounds that inhibit copper catalysis. *J. Biol. Chem.* 128: 447–453.
25. Gutstein, M. 1932. Bestimmung der H-Konzentration in der lebenden Hefe- und Bakterienzelle. *Protoplasma*, 17: 454–470.
26. Haldane, J. B. S. 1930. Enzymes. Longmans, *London.*
27. Harden, Arthur. 1932. Alcoholic Fermentation. 4th. ed. Longmans. *London.*
28. Harvey, E. Newton, and C. C. Taylor. 1934. The oxygen consumption of luminous bacteria in water containing deuterium oxide. *J. Cell. Comp. Physiol.* 4: 357–362.
29. Heilbrunn, L. 1928. Colloid Chemistry of Protoplasm. Borntraeger, *Berlin.*
30. Johnson, Frank H. 1936. The aerobic oxidation of carbohydrates by luminous bacteria, and the inhibition of oxidation by certain sugars. *J. Cell. Comp. Physiol.* 8: 439–463.
31. Krahl, M. E., and G. H. A. Clowes. 1938a. Physiological effects of nitro- and halo-substituted phenols in relation to extracellular and intracellular hydrogen ion concentration. I. Dissociation constants and theory. *J. Cell. Comp. Physiol.* 11: 1–20.
32. ——, and ——. 1938b. Physiological effects of nitro- and halo-substituted phenols in relation to extracellular and intracellular hydrogen ion concentration. II. Experiments with *Arbacia* eggs. *J. Cell. Comp. Physiol.* 11: 21–39.
33. Landahl, Herbert D. 1937. Mathematical biophysics of cell respiration. *Growth*, 1: 263–277.
34. Langmuir, Irvin. 1932. Vapor pressure, evaporation, condensation, and adsorption. *J. Amer. Chem. Soc.* 54: 2798–2832.
35. Lillie, R. S. 1902. The role of the cell nucleus in oxydation and synthesis. *Amer. J. Physiol.* 6: xv–xvi.
36. Lineweaver, Hans. 1933. Characteristics of oxidation by Azotobacter. *J. Biol. Chem.* 99: 575–593.
37. Lineweaver, Hans, and Dean Burk. 1934. The determination of enzyme dissociation constants. *J. Amer. Chem. Soc.* 56: 658–666.
38. Loeb, J., and H. Wasteneys. 1912. Die Oxydationsvorgänge im befruchteten und unbefruchteten Seeternei. *Arch. Entwick. Organ.* 35: 555–557.
39. ——, and ——. 1913. The influence of hypertonic solutions upon the rate of oxidation in fertilized and unfertilized eggs. *J. Biol. Chem.* 14: 469.
40. Lyon, E. P. 1904. Rhythm of $CO_2$ production during cleavage. *Sci.* 19: 350–353.
41. McCutcheon, Morton, and Baldwin Lucké. 1933. The effect of temperature on permeability to water of resting and of activated cells. *J. Cell. Comp. Physiol.* 2: 11–26.
42. Mast, S. O., D. M. Pace, and Louise Mast. 1936. The effect of sulfur on the rate of respiration and on the respiratory quotient in *Chilomonas paramecium*. *J. Cell. Comp. Physiol.* 8: 125–139.
43. Meldrum, Norman, U. 1934. Cellular Respiration. Methuen, *London.*

44. Michaelis, L., and M. L. Menten. 1913. Die Kinetik der Invertinwirkung. *Biochem. Zeitschr.* 49: 333–369.

45. Osterhout, W. J. V. 1917. The role of the nucleus in oxidation. *Sci.* 46: 367–369.

46. Pirson, Andre. 1939 Über die Wirkung von Alkalionen auf Wachstum und Stoffwechsel von *Chlorella*. *Planta*. 29: 231–261.

47. Plantefol, L. 1933. L'action du dinitrophenol 1.2.4 sur la respiration de levures. *Compt. Rend. Soc. de. Biol.*, 113: 147–150.

48. Pratt, Ernst, and Roger Williams. 1939. The effect of pantothenic acid on respiratory activity. *J. Gen. Physiol.* 22: 637–647.

49. Rahn, Otto. 1934. Chemistry of death. *Cold Spring Harbor Symp. Biol.* 2: 70–77.

50. Rashevsky, Nicolas. 1938. Mathematical Biophysics. Univ. Chicago Press.

51. Rubenstein, B. B. 1932. The kinetics of intracellular carbohydrate oxidation of *Sarcina lutea*. *J. Cell. Comp. Physiol.* 2: 27–40.

52. Rubenstein, B. B., and R. W. Gerard. 1934. Fertilization and temperature coefficients of oxygen consumption in eggs of *Arbacia punctulata*. *J. Gen. Physiol.* 17: 677–685.

53. Runnström, J. 1930. Atmungsmechanismus und Entwicklungserregung bei dem Seeigelei. *Protoplasma* 10: 106–170.

54. Shapiro, Herbert. 1935. The respiration of fragments obtained by centrifuging the egg of the sea urchin, *Arbacia punctulata*. *J. Cell. Comp. Physiol.* 6: 101–116.

55. Shearer, C. 1922. On the oxidation processes of Echinoderm eggs during fertilization. *Proc. Roy. Soc. Lond.* B 93: 213–229.

56. Shibata, M. 1919. Über die Wirkung der Elektrolyten auf den Sauerstoffverbrauch von *Chlorella ellipsoidea*. *Sci. Rep. Tohoku Imp. Univ.* 4: 431–471.

57. Shoup, Charles S. 1929. The respiration of luminous bacteria and the effect of oxygen tension upon oxygen consumption. *J. Gen. Physiol.* 13: 27–45.

58. Shoup, Charles S., and Alexander Kimler. 1934. The sensitivity of the respiration of luminous bacteria for 2,4-dinitrophenol. *J. Cell. Comp. Physiol.* 5: 269–276.

59. Snyder, Charles D. 1931. Quantitative relations in biological processes and the radiation hypothesis of chemical activation. Quart. Rev. Biol. 6: 281–305.

60. Specht, Heinz. 1934. Aerobic respiration in *Spirostomum ambigum* and the production of ammonia. *J. Cell. Comp. Physiol.* 5: 319–333.

61. Stephenson, Marjory. 1939. Bacterial Metabolism. 2nd. ed. Longmans, *London*.

62. Stier, T. J. B., and J. N. Stannard. 1936. A kinetic analysis of the endogenous respiration of baker's yeast. *J. Gen. Physiol.* 19: 461–477.

63. Swann, W. F. G., and C. del Rosario. 1932. The effect of certain monochromatic ultra-violet radiation on *Euglena* cells. *J. Franklin Institute*, 213: 549–560.

64. Tang, Pei-sung. 1931. The oxygen-tension-oxygen consumption curve of unfertilized *Arbacia* eggs. *Biol. Bull.* 60: 242–244.

65. ——. 1931a. The rate of oxygen consumption of *Asterias* eggs before and after fertilization. *Biol. Bull.* 61: 468–471.

66. Tang, Pei-sung. 1933. On the rate of oxygen consumption by tissues and lower organisms as a function of oxygen tension. Quart. Rev. Biol. 8: 260–274.

67. Tang, P. S. 1936. Studies on the kinetics of cell respiration. I. The rate of oxygen consumption by *Saccharomyces wanching* as a function of pH. *J. Cell. Comp. Physiol.* 7: 475–493.

68. ——. 1936a. Studies on the kinetics of cell respiration. II. Parallelism between the rate of oxygen consumption by *Saccharomyces wanching* and the change in optical rotation of glucose in boric acid buffers. *J. Cell. Comp. Physiol.* 8: 109–115.

69. ——. 1936b. Studies on the kinetics of cell respiration. III. The effect of ultraviolet light on the rate of oxygen consumption by *Saccharomyces wanching*. *J. Cell. Comp. Physiol.* 8: 117–123.

70. ——. 1937. Studies on the kinetics of cell respiration. VI. Respiration of Chlorella pyrenoidosa in presence of lactates. *J. Cell. Comp. Physiol.* 10: 499–511.

71. ——, and C. S. French. 1933. The rate of oxygen consumption by *Chlorella pyrenoidosa* as a function of temperature and of oxygen tension. *Chinese J. Physiol.* 7: 353–378.

72. ——, and R. W. Gerard. 1932. The oxygen tension-oxygen consumption curve of fertilized *Arbacia* eggs. *J. Cell Comp. Physiol.* 1: 503–513.

73. ——, and C. Y. Lin. 1936. Studies on the kinetics of cell respiration. IV. Oxidation reduction potentials of *Chlorella* suspensions in light and in darkness. *J. Cell. Comp. Physiol.* 9: 149–163.

74. ——, and ——. 1937. Studies on the kinetics of cell respiration. V. Effect of certain organic compounds on the rate of oxygen consumption and $CO_2$ production by *Saccharo-*

*myces wanching*. *J. Cell. Comp. Physiol.* 10: 487–498.

75. Tang, P. S. and Mao-i Wu. 1938. Studies on the kinetics of cell respiration. VII. Respiration of *Saccharomyces wanching* in acetate, lactate and pyruvate buffer solutions. *J. Cell. Comp. Physiol.* 11: 495–502.

76. Vlès, Frédd. 1912. Sur les variations des ions H au voisinage des oeufs en division. *Compt. Rend. Acad. Sci. Paris.* 175: 643–646.

77. Warburg, O. 1914. Zellstruktur und Oxydationsgeschwindigkeit nach Versuchen am Seeigelei. *Pflüger's Arch. Gesamte Physiol.* 158: 189–208.

78. ——. 1915. Notizen zur Entwicklungsphysiologie des Seeigeleis. *Arch. Gesamte Physiol.* 160: 324–332.

79. ——. 1928. Über die katalytische Wirkungen der lebendigen Substanz. *Berlin.*

80. ——. 1930. Metabolism of Tumors. [Translated by Frank Dickens] Constable. *London.*

81. ——, und F. Kubowitz. 1929. Atmung bei der kleinen Sauerstoffdrucken. *Biochem. Zeitschr.* 214: 5–18.

82. ——, und O. Meyerhof. 1912. Über Atmung in abgetötetten Zellen und in Zellfragmenten. *Pflüger's Arch. Gesamte Physiol.* 148: 295–311.

83. Wertheimer, Ernst. 1934. Über die ersten Anfänge der Zuckerassimilation. Versuche an Hefezellen. *Protoplasma* 21: 522–560.

84. Whittaker, D. M. 1933. On the rate of oxygen consumption by fertilized and unfertilized eggs. V. Comparisons and interpretation. *J. Gen. Physiol.* 16: 497–528.

# FORM AND FUNCTION IN THE SLOTH (*Concluded*)

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### *Young sloths*

YOUNG sloths are active almost from the moment they are born. Shortly thereafter, on emerging from the epitrichium, they crawl upon their mother and begin nursing; or they may "lose" their mother for a while and climb around in the neighboring branches or on the sides of the cage. Apparently they see well at this time. For three or four months after birth they are attractive, furry creatures; when picked up they readily crawl to the inside of one's coat, possibly for warmth, and hold on with great tenacity by their sharp claws.

While two-toed sloths guard their young jealously (Fig. 4, *3*, *4*), three-toed animals often show only slight regard for their offspring. Sometimes *Bradypus* may reach out and draw its young toward it, but at other times a stray baby may squeal for hours only a few feet from its mother, without any move being made by the latter to recover it. Although it clings to the sheltering breast or back with all its might, and may be dislodged only with difficulty, the young *Bradypus* may be taken from its mother with little maternal resistance. Sometimes, however, the mother may crawl away or make an attempt to fight. Males show no regard for the young.

Evidently one sloth only is born at a time; the uterus has never been found to contain more than one fetus, and mothers have never been observed with more than one young accompanying them. The young sloth often stays with its mother for six months or more, and gradually becomes accustomed to leaving the parental fur until it finally takes its place in the jungle as a solitary wandering individual. It does not really set forth in many cases, it would seem, until the appearance of another member of the family is almost at hand. One author (Beebe, 1926) has stated, however, that the young *Bradypus* may be weaned at 4 or 5 weeks of age.

### *A lowly but specialized mammal*

Several low-grade Eutherian characteristics are shown by sloths. Anatomically, the variable number of cervical vertebrae and the occasional presence of a complete coracoid may be mentioned. Further, the sloth skull is coarse and variable in structure, and the mandibular angle also varies in different specimens. Because of such conditions, a number of different species have been erroneously described by earlier workers. The vascular bundles, intra-abdominal testes, simple uterus and non-lobate lungs also indicate a low type of organization.

On the functional side, sloths show a low and widely-varying body temperature, and an inability to withstand moderate extremes of climate. *Bradypus* is in the latter respect greatly handicapped, and both genera are restricted to well-defined latitudes. The slow and often

irregular movements of sloths are again indicative of low-grade neuro-muscular organization and co-ordination. In keeping is the slow rate of digestion of food-stuffs. Other characteristics will be mentioned later.

Notwithstanding these and many other restrictions, the sloth appears to be the most highly adapted and specialized form for sustaining an arboreal life. Safety has of necessity been a prime factor in its evolutional history, and marvellous clinging ability along with slow and sure movement have been developed. Life for it on land would be quite insupportable. The long, recurved claws, incapable of individual action (the manus being reduced to a hook—Fig. 14); the long, slender limbs with rotating radius and manus and pes normally facing inwards; the triangular, climbing type of scapula with large or separate coracoid, and the small pelvis—all are particular arboreal adaptations. The well-developed lateral abdominal wall and the peculiar blood-vascular plexuses may also be included.

Of the two genera, *Cholepus* is the better fitted for its habitat, and shows the greater specialization. The didactylate fore-limb and shorter hind-limb, large palmar and plantar pads (bare to aid in clinging), and complete absence of tail are striking characteristics. *Cholepus* rarely sets foot on terra firma, but *Bradypus* does fairly often. The fore-claws of *Bradypus* are somewhat longer, and those of the hind limb are shorter, than those of *Cholepus*. In *Bradypus* the fore-claws are as long as a man's fingers, and deeply grooved on the concave aspect. Comparing animals of similar weight (about 3.5 kgs.), the claws averaged in length as follows:—

*Bradypus griseus:*
Fore-claws, 7.0 to 8.0 cms.
Hind-claws, 5.0 to 5.5 cms.

*Cholepus hoffmanni:*
Fore-claws, 5.5 to 6.5 cms.
Hind-claws, 5.0 to 6.5 cms.

*Bradypus* is said to have lost the first and fifth toes, and *Cholepus* the fourth also in the fore-limbs. However, in a polydactylic case in which all five claws were present in the right hind limb of *Bradypus* (Fig. 14), the first digit was non-functional and the second showed only slight tonus and resistance. This would suggest the loss of the first and second toes in the normal tridactyl form.

The paws and claws may be used together very capably in drawing down and holding suspended fruits. Bananas and other fruits and objects may be held and manipulated with a nicety, indeed, when occasion demands it. It may be observed that when placed on the ground the sloth is able to oppose the manus and foot, as other plantigrade forms.

### *Osteology*

The skull of *Bradypus* is small and ovate, and that of *Cholepus* slightly larger and somewhat more rounded. In both cases the skull plates are quite thick and strong. It is said nevertheless that the Jivaro Indians of the Amazon, known for their unpleasant custom of making shrunken mummies of their enemies' heads, employ the sloth as a subject of experiment for training boys in this art (Tevis, 1925). Wide variation in skull shape is found in different sloths. The zygomatic arch is incomplete, and the premaxillae almost absent.

The teeth are reduced to five in the upper and four in the lower jaw, incisors and canines being absent. It is interesting to note in this connection that the organs of Ackerknecht, paired epithelial bodies found under the tongue in the embryos of many higher mammalian forms and said to be related to the develop-

ment of the incisor teeth, are present in both didactyl and tridactyl sloth fetuses in which no evidence of incisors appears (Coebergh, 1930). The first lateral teeth in *Cholepus* are large, long, and pointed like canines, and the upper shear with the lower, giving great aid in feeding and constituting formidable weapons. All the teeth grow from persistent pulps and have no enamel, but a thin, hard coat of dentine is present. This forms a ridge around the upper tooth surface as the soft vasodentine enclosed wears away. No milk teeth are known. The dental characteristics thus appear to represent a primitive condition, and possibly are degenerate from a higher Eutherian type. Practically all the exposed tooth surfaces are covered with dark brown or black deposits, probably derived from the peculiar leaf (cecropia?) and fruit diet of sloths.

The eyes may be retracted deeply within the orbit at will, in both genera. Rods only are present in the retina (Wislocki, 1928), indicating that sloths are more active by night than by day. In the day the pupil is of pin-point dimensions, while at night it is wide open and responds very slowly to light. The bright yellow reflection from the tapetum of the eye at night, when a light is thrown upon it, also indicates that sloths are nocturnal in their habits.

The remarkable number of nine or even ten cervical vertebrae occurs in *Bradypus*, in contrast to the normal seven in most mammals. Cervical ribs are found on the ninth and sometimes even the eighth cervical vertebrae in this animal. There are fourteen to seventeen thoracic vertebrae. In *Cholepus* there are six (sometimes seven) cervical vertebrae, and twenty-three or twenty-four thoracic vertebrae. Miller (1935), Straus (1937), and others have discussed several aspects of the sloth vertebral column.

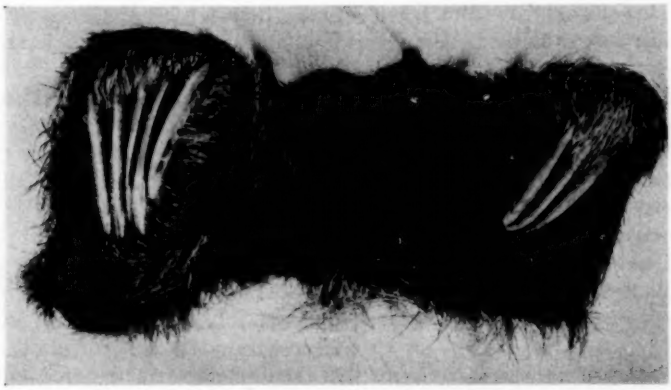

FIG. 14. AN UNUSUAL CASE OF POLYDACTYLISM IN THE HIND LIMB OF THE THREE-TOED SLOTH
On the right side, five claws are present instead of the normal three

Considering the anatomical features of the trunk, an interesting comment has been made by Howell (1930). The construction of the chest between the pendant arms would lead one to expect a narrowing in this region, he remarks, but on the contrary the sloth chest is much broader than it is thick. Muscle pull does not appear to be an important factor therefore in the expected direction; rather, a sig-

nificant influence on the thorax has been the removal of the ventral gravitational pull, permitting the ribs to spring outward.

### *Skeletal muscle*

While probably all other mammals possess some amount of white or pale skeletal muscle, that of the sloth is uniformly red in character (Wislocki, 1928). It would thus appear that all sloth muscle is fundamentally unsuitable for quick or delicate reactions, for which white muscle with its finer translucent fibers containing large amounts of glycogen is generally utilized. The glycogen percentage in sloth muscle is low in comparison with other animals, although to be sure this substance may not be specifically related to rapidity of action.

In microscopic sections the muscle fibers appear uniformly large and coarse, according to Wislocki (1928), and they are easily separable as distinct fibers. Cross-striations are present as in other mammalian muscle. The nerve supply shows no unusual difference from other types. From the arterial and venous plexuses in the upper parts of the limbs, vessels are said to go to and from the skeletal muscle tissues; in the muscle masses themselves, however, no unusual vascular arrangement is found.

The fact that only about half the percentage amount of skeletal muscle found in other mammals is present in sloths has been referred to elsewhere. The extremely long, thin limbs observed in animals shorn of hair, and the thin streamlined body (but not built for speed), also indicate the extraordinarily small amount of muscular development (Fig. 6). The thick, broad bands of muscle placed laterally in the abdominal wall (panniculus carnosus) are probably related to the demands for support in the inverted position.

When operating on or dissecting out skeletal muscle, it may often be observed to undergo slow contractions of a tetanic nature.

### *Gastro-intestinal tract*

The stomach of the sloth is extremely large, and when normally full (as it has almost invariably been observed to be, in some two hundred animals) it fills up the whole anterior part of the abdominal cavity. From twenty to over thirty per cent of the body weight may be represented by stomach and contents. After three to six days of fasting the stomach is found to be only slightly less full, and it would thus seem possible that the gastric food stores of the sloth might serve on demand for perhaps several weeks of fasting. X-ray pictures support the observation that gastro-intestinal movements progress slowly, in keeping with the general economy of the animal (see later).

On general inspection the full sloth stomach appears in the main as a large, well-rounded mass, almost as large as a man's head. Closer observation reveals some small folds on the inner curvature, indicating the presence of partially separated sacs; also, three smaller chambers are found connecting with the pylorus. A large, tapering and curving (crescent-shaped) appendage or cecum, 15 to 20 cms. long and about 5 cms. in diameter at the upper end, arises from the inferior and outer aspect of the main Bradypodine stomach. In *Choloepus* a similar appendix is present, but it is much smaller—usually about 3 cms. only in length. There are thus four distinct gastric chambers and an appendix, as well as other partially divided and probably functionally separate sacs, in didactyl and tridactyl sloths.

In many respects the tardigrade stomach resembles that of the sheep (Fig. 15).

Dissection showed a relatively thick-walled organ with many chambers, and coarse rugae and deep folds extending throughout the greater part of the main gastric chamber. Bars of muscle tissue crossed the upper part of this chamber, and connected with a large muscular ring delimiting a smaller deep chamber (Fig. 16). From the main part of the stomach the fresh mucosa with water. This area undoubtedly represented the acid-secreting part of the stomach. Below the pylorus the intestine showed a diminishingly acid reaction for 60–100 cms. of its length.

The distal compartment adjoining the pylorus showed a heavy muscular wall, several mms. in thickness, with coarse mucosal lining (Fig. 16). Usually several grams of semi-dry, fibrous, and seedy materials were found in it. Other charac-

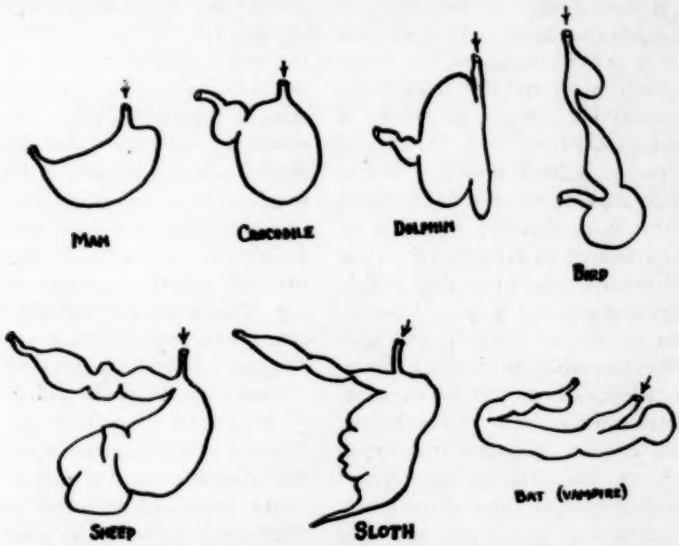


FIG. 15. A COMPARISON OF THE SLOTH STOMACH WITH THAT OF OTHER ANIMAL TYPES

the three smaller chambers, in series and somewhat cone-shaped, lead towards the intestine. The pyloric opening, not specially muscular, was about 5 cms. long by 2 cms. in diameter. The mucosa of the large gastric chamber was dull pink in color, and that of the appendix a brighter red; all other parts were a grayish color. The chambers leading to the pylorus gave acid reactions as indicated by litmus, the middle of the three showing an extremely strong reaction which did not disappear after several washings of teristics also present were strongly indicative of a gizzard-like organ, capable of exerting considerable pressure on contained foodstuffs. Its distinct sac formation distinguished it from an ordinary pylorus.

The gastric appendage of the tridactyl sloth is divided almost equally in half along its length internally by a strong, mucosa-covered septum; thus two orifices are present, both giving entrance to the main gastric chamber (Fig. 16). In several animals which were examined,

the appendix contained large amounts of a thick, dark green fluid, or sometimes the mass was putty-like, of uniform smooth texture and consistency. The color and character of the material suggested its similarity to bile, but this seemed hardly likely; also, several of the usual tests for this substance proved negative. No correlation of the gastric appendix with the absence of a gall bladder in this animal was apparent. In experiments in which the appendage was evacuated and then blocked by tampon at the entrances into the stomach, the organ gave no evidence of important secretory activity over periods of several days, and only a small amount of mucus appeared in the cavities.

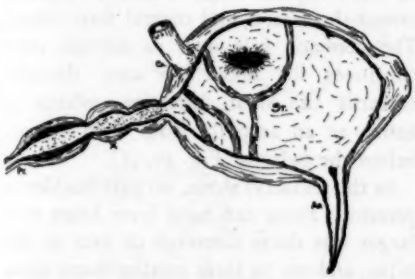

FIG. 16. SEMI-DIAGRAMMATIC SKETCH OF THE EXPOSED GASTRIC CHAMBERS OF THE THREE-TOED SLOTH

Note heavy muscle bands on the inner half of the main stomach (ST.), the long appendix (AP.) with dividing membrane, and the thick muscular wall of the pre-pyloric chamber. The chamber X gives a strongly acid reaction. CA. = cardia and PT = pylorus.

The polysacculate gastric apparatus of sloths suggests that the alimentary processes would be involved and protracted, and so indeed they are, as will be indicated later. In passing, an amusing essay by Athill (1937) contains the reflection that life for the sloth with its four stomachs "can never lack absorbing interest."

Below the stomach the intestine continues as one long, folded tube without appendices. The transition from small to large intestine is not very marked, there being a gradual funnelling out to about twice the diameter over a length of several cms., without valvular interruption or gross change (except size) in tubal character.

A cecum is absent, as it is also in some cetacea and a few carnivores. The rectum shows a large pouch or sac in which considerable quantities of fecal masses may be stored. Anal glands are seen in *Cholepus*.

In the anesthetized sloth the exposed gastro-intestinal apparatus usually appears quiescent; cooling initiates contractions, as also does gentle manipulation. Weak faradic shocks of low frequency produce slow contractions which may extend a few centimeters along the tract. Waves of contraction may arise after exposure and partial drying of the intestines. Contractions of the lower part of the stomach appeared on electrical stimulation of the right vagus in the thorax. All the direct observations on gastro-intestinal contractions in sloths indicated that the movements were extremely slow relative to those in other forms, but otherwise similar in character.

In several didactyl sloths the gastro-intestinal movements were observed by X-rays after a barium test meal had been given. These studies (carried out on imported sloths at the University of Virginia) indicated that food such as bananas and citrus fruits may remain in the stomach from 70 to 90 hours, and even longer, after ingestion. During this time small amounts of the digested foodstuffs may be slowly passed on to the intestine, and towards the end of the period food residues begin to appear as small rounded pellets in the rectum. In some cases a week or so may be taken to make the transit of the alimentary canal!

The rectum of the experimental animal has often been found greatly distended with hard fecal pellets, a centimeter or so in diameter. The living animal may accumulate for several days and later excrete large masses of this material, up to a pound or two in weight at one time. At both ends of the gastro-intestinal tract, therefore—the stomach and rectum —the sloth shows extreme smooth-muscle sluggishness, in noteworthy agreement with its skeletal muscular slowness.

*Other abdominal organs*

The spleen in *Cholepus* is variable in shape and size; it is sometimes triangular and flat, but more often semi-lunar with ragged edges, about 5 cms. long by 2.5 cms. wide and 0.5 cm. thick, and 6 to 8 gms. in weight. In *Bradypus* the organ is somewhat longer and irregularly cord-like, about 7 to 8 cms. by 1.5 cms. by 0.5 cm., and 3 to 6 gms. in weight. Free accessory splenic nodules are often found.

The liver of sloths is somewhat small for the size of the animal, varying between 1 and 2 per cent only of the body weight. The smallest relative sizes are observed in the three-toed form, in which there are two main liver lobes. In the didactyl sloth there are three main liver lobes, with another lobe division only slightly marked.

deBurlet (1911), Wislocki (1928), and others have commented on an apparent rotation of the liver resulting in transposition of the lobes in sloths, and sought explanation for the condition. Broman (1929), however, states that conditions in sloths are in principle the same as in other mammals, and partial modification of mesogastria and liver ligaments has occurred because of the great enlargement of the stomach.

A small pear-shaped gall bladder, 1 to 2 cms. long, and simple with straight neck, is found in *Cholepus* on the visceral aspect of the liver, situated centrally between the two large medial lobes and usually half buried or more in the parenchyma. The wall is of normal thickness, but appears fibrous in texture and non-muscular, and the mucosa is granular in appearance. It contains from 1 to 2 cc. of highly viscid bile. The cystic duct proceeds from the gall bladder along the inferior surface and close to the liver for a few centimeters, and is then joined by two or more (sometimes four or five) hepatic ducts which course between the lateral and central liver lobes. The common bile duct so formed then continues for about 10 cms. directly towards the small intestine, which it enters at an ampulla from 3 to 4 cms. below the pylorus (Fig. 17, *A*).

In the tridactyl sloth, no gall bladder is present. From the main liver lobes two larger bile ducts converge to join in the hilus, and one to three smaller ducts unite with these, without unusual enlargement, to form a common duct. The latter proceeds about 10 cms. towards the small intestine, into which it empties by a definite ampulla about 15 cms. below the pylorus (Fig. 17, *B*).

Attention has been drawn to the presence of a large gastric appendage in the three-toed sloth which normally contains a thick, viscid material much like bile, but gives none of the ordinary bile reactions. The possibility of a functional correlation of this organ with the absence of a gall bladder may be mentioned. By contrast, only a very small gastric appendix is found in the two-toed sloth, in which the gall bladder is present.

The pancreas is of moderate size, partly compact and partly diffuse, in both *Bradypus* and *Cholepus*. In histological preparations Islets of Langerhans are observed. A duct runs through the main

mass of tissue and enters the intestine at an ampulla about 15 cms. below the pylorus in the two-toed animal, and 10 to 12 cms. below in the three-toed form.

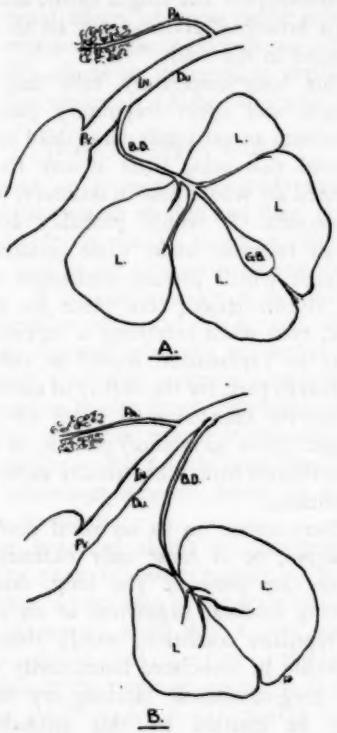


FIG. 17. SKETCH SHOWING THE RELATIONS OF LIVER (L.) AND INTESTINE (IN.), AND BILE AND PANCREATIC DUCTS (B.D. AND P.A.), IN (A.) TWO-TOED AND (B.) THREE-TOED SLOTHS

Note that in the entry of the ducts into the intestine, the relations are reversed in the two cases. There is a simple gall-bladder (G.B.) in the two-toed sloth, and none in the three-toed form. The liver in the latter animal is very small and relatively simple in type.

The relations of the bile and pancreatic ducts are shown in the accompanying illustration (Fig. 17). The entrance of the bile duct into the upper part of the duodenum well above the pancreatic duct in the two-toed sloth which possesses a gall-bladder, and low down and distal to the pancreatic duct in the case of the three-toed animal (without gall bladder) should be emphasized. The morphological conditions possibly involve functional correlations. Obviously in the former case bile reaches the intestine and may thus act upon food materials before the pancreatic juice, while in the latter the reverse situation is present.

The kidneys and the adrenals, all relatively small organs in the adult, are in both forms of a lowly mammalian type, oval and smooth. The former are rather far down in the abdominal cavity at the rim of the pelvis, and the latter are found two or three cms. anteriorly. In several fetuses examined the adrenals were adjacent to the kidneys and strikingly large; in the smaller fetuses they were even larger than the kidneys, and consisted almost wholly of well-differentiated cortical tissue. Wislocki (1928) also observed that the fetal adrenals were in one case much larger than the kidneys. The urine in several tests was slightly alkaline in reaction, and in others slightly acid, in three-toed sloths especially.

The intra-abdominal testes are small and round and deeply situated between the rectum and bladder. Seminal vesicles have been observed in both *Cholepus* and *Bradypus*—large in the former and small and rudimentary in the latter (Wislocki, 1928). The ovary is bilobed, and is situated in a uterine pouch. The vagina is double in its lower third, and thus possesses two small outlets.

There is a small compact thymus. The thyroid is represented by a very small, rod-shaped mass on each side, with a relatively poor blood supply. Such an organ could hardly be expected to influence body metabolism to any noteworthy extent. Parathyroid glands are said to be

present (Wislocki, 1928). A description of the hypophysis has also been given by Wislocki, and special attention drawn to the absence of the pars tuberalis. The latter point emphasizes the doubt that this part of the pituitary body possesses any highly specialized function.

*Respiratory apparatus*

The trachea in the three-toed sloth was first described by Weber (1904), and is

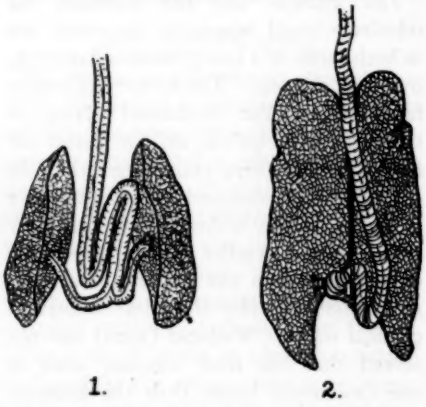


FIG. 18. SKETCH OF TRACHEA AND LUNGS IN THREE-TOED SLOTHS

1, in fetus near term, viewed anteriorly, the tracheal turns are very prominent; 2, in adult animal, seen posteriorly, the pre-bronchial ampulla is marked. The trachea in *Bradypus* is seen to be extremely long, reaching to the diaphragm and curving twice before giving off the bronchi.

strikingly unique. It is extremely long, running through the thoracic cavity dorsally and between the lungs for 12 to 15 cms. to reach the diaphragm; on the latter it recurves, proceeds anteriorly for 2 to 4 cms. and again curves slightly ventrally for a centimeter or so before opening into a sac or an ampulla about 0.75 cm. in diameter. From the latter the right and left bronchi are given off; each bronchus is 2 to 3 cms. long, of large calibre, and shows two or three shallow sacculations. In the fetus the tracheal double turn is more defined, and the ampulla is less marked (Fig. 18). Blume (1928) has remarked on the fetal relationships. The length of the trachea to its bronchial division may be 20 cms. or more in the adult.

This long respiratory tube and the bronchi and upper respiratory passages constitute an extremely large dead space. Beyond this area, little if any freshly inspired air would pass in ordinary, quiet respiration. It would probably act as an air reservoir under some conditions, through which gaseous exchanges with the alveoli might take place for some time, even when breathing is suppressed. Thus an explanation would be offered, at least in part, for the ability of the sloth to survive immersion in water for prolonged (30 or 40 minute) periods, as well as to recover from other usually asphyxial conditions.

There appear to be no vocal cords in *Bradypus*, or at most only rudimentary tissues are present. The long, doubly-curving trachea, suggestive of an avian or reptilian condition, would therefore probably be associated functionally with the long-continued, bleating cry which may be emitted by this animal. In didactyl sloths the tracheal arrangements and vocal cords are similar to those found in other mammals.

There are slight indications only that the lungs may be divided into upper and lower lobes (Fig. 18, 2). The respiratory surface is apparently extremely small compared to other animals. While the number of air cells (alveoli) in the cat, for example, has been estimated at 400,000,000, and the respiratory surface is equal to about 20 square meters, the respective figures in the sloth were only 6,250,000 cells with a surface of 5 square meters (Howell, 1930).

The respiratory rate varies in different animals from 10 to 15 cycles per minute, and rises on excitement or activity to 20 to 30 per minute. Normally, a rather shallow type of breathing is observed. The usual effects of vagal nerve section and stimulation, the Hering-Breuer reflex, and $CO_2$ effects are observed in sloths as in other mammals (Almeida, 1928).

### *Tissue and organ weights*

About 20 per cent of the body weight of sloths consists of skin and hair, about 25 per cent is muscle, 20 to 25 per cent bone, and 25 per cent stomach and intestines. A striking amount of the animal is therefore skin and bone, and these tissues together with the ponderous alimentary tract and contents constitute a tremendous burden for the relatively small amount of skeletal muscle in this animal. The muscle is only a little more than half the percentage amount found in most other mammals.

The heart of sloths is considerably smaller than in other mammals, being less than 0.3 per cent of the body weight. The three-toed sloth has a very small liver—a little over 1 per cent of the body weight; in the two-toed animal it is also rather small—about 2 per cent of body weight. The intra-abdominal testes in all sloths are very small—only 0.13 per cent of the body weight. The brain (including cerebellum), in several cases which were examined, was about 0.6 per cent of the body weight, a high figure for a low-type of mammal. It should be said that in these and all other cases determinations were made on day-fasting animals, and no corrections were made for the large stomach, fecal residues, etc., found in sloths.

Figures for other organs observed by the author, given in percentage of body weight, are as follows:—Two-toed sloths: kidneys 0.54, spleen 0.19, pancreas 0.33, adrenals 0.02, ovaries 0.03, lungs 0.59. Three-toed sloths: kidneys 0.43, spleen 0.11, pancreas 0.33, adrenals 0.015 (male) and 0.022 (female), ovaries 0.03, lungs 0.79. Combined weights are considered in the case of bilaterally represented organs.

### *Blood and circulation*

In operative procedures on sloths the tissues appear somewhat pale and do not bleed readily, and it would seem that these animals are not as vascular as most higher forms. However, blood volume levels have not been ascertained. It is rather difficult to secure a few cc. of blood, from tridactyl sloths especially, unless a rather large vessel be entered. Probably the relatively low pressures in the vascular plexuses are explanatory of the conditions. A good systolic arterial pressure between 120–140 mm. Hg is maintained in didactyl animals, and vascular responses to adrenal stimulation and various excitatory conditions are in keeping with those derived from other types.

Reference has been made to the work of Wislocki (1928) for many points on the circulation in sloths. The brachial, hypogastric, and iliac arteries are said to send off numerous small vessels to form remarkably rich arterial plexuses (retia mirabilia), running for some distance with the main arteries, in the fore and hind limbs. In close correlation is a plexiform arrangement of small veins with anastomoses returning blood from the limb areas.

The small arterial vessels are found to run in close bundles surrounded by connective tissue for some distance before branching off to the muscles; along with the venous plexuses they are chiefly noticeable in the proximal parts of the limbs. Somewhat similar conditions have been found in other Edentates and

in some marsupials, rodents and other forms; they are observed particularly, however, in the older or less differentiated mammalian types, and probably represent an archaic condition.

Much discussion has ensued regarding the function of such unusual vascular plexuses. From all appearances they serve specifically the skeletal muscle tissues, and many have suggested their possible involvement in the maintenance of blood flow during slowly-developed and long-sustained tetanic contractions. That such a manifold vascular branching would result in a very low blood pressure in the small vessels eventually reaching the muscles would appear certain. The conditions would nevertheless facilitate the *perfusion* of blood through all the muscle fibers, and serve to maintain the flow continuously under the peculiar and difficult gravitational influences involved in the "upside-down" position. The amount of blood flowing in unit time through a unit of muscle tissue, that is to say, would be well maintained. The plexiform arrangement of veins, as well as the posture of the animal, would also materially aid in venous return to the heart.

It would appear therefore that a functionally simplified blood-vascular apparatus is provided for the limbs, in inactive or posturally unique forms such as the sloth. It may be remarked further that the metabolic demands for the simple maintenance of tone—and the sloth is occupied most of its life in keeping up tonus—are much smaller than for actual contraction of muscle, and the supply of blood at a high pressure would not be an imperative demand.

Sloths and other Edentates usually possess a double vena cava, or two venae cavae, one on either side of the aorta, which unite mid-abdominally. In the sacral region large branches are given off and enter the vertebral canal to unite with other veins there, and thus much of the blood from the hind limbs reaches the heart by a relatively abnormal manner via several enlarged thoracic intervertebral foramina, without going through the liver. Posture and gravity influences have possibly brought about this very unusual vascular arrangement, although somewhat similar conditions said to have been detected in ground-living "ancestors" of present-day sloths would tend to invalidate a mechanical explanation (de Burlet, 1922; Wislocki, 1928; Wislocki and Straus, 1932).

The blood cells of sloths are not notably different from those observed in most other mammalian forms. The erythrocytes may sometimes be found elliptical or distorted in smears, but for the most part they appear as circular biconcave discs. The leucocytes seem rather small compared to other types, but no special study has been made of these cells. Free histiocytes have been observed in sloth blood (Oria, 1929).

Some determinations of blood constituents have been made in the course of other studies. The blood sugar in both *Choloepus* and *Bradypus* approximates the levels found in other mammals—usually between 75 and 95 mgs. per cent, with a range of 65 to 165 mgs. In disturbances such as emotion, increases of 50 per cent or more above normal may occur fairly readily. Serum sodium, potassium and chloride levels were on the average 130, 5.5 to 7.5, and 100 mE. per liter respectively. The values for sodium and chloride are observed to be much lower—from 10 to 25 per cent—than in animals such as cats or dogs. The urea in the serum averaged 100 mgs. per cent in two-toed sloths, and 80 mgs.

in the three-toed form—in both cases much greater than in most mammals.

Sloths appear to be richly supplied with lymphatic vessels and glands, the latter being rather small in the thoracic and abdominal cavities. Wislocki (1928) has observed that in the abdominal area the lymphatics empty into the vena cava and portal vein, and no thoracic duct is therefore formed.

### *The heart*

The heart rate in *Bradypus* in the quiet state is usually between 60 and 110 per minute, and in *Cholepus* somewhat higher, between 70 and 130 per minute. Fairly quick accelerations of 20 to 40 per cent are observed on exercise and excitement, and also on adrenal massage. Inhibition occurred almost immediately on stimulating the vagus nerve in the neck in *Bradypus*, and in the thorax just above the heart in *Cholepus*. Both right and left nerve stimulation was effective, and the heart rate was reduced to 20 or 30 beats per minute. No standstill was produced. In several attempts, vagus stimulation in the cervical region, however, was without effect in *Cholepus*. Electrocardiographic records were essentially similar to those derived from most other mammals.

The heart is moderately well supplied with glycogen, usually averaging between 0.5 and 0.6 mg. per cent.

The extremely small size of the heart in sloths—about half that found in man and high-class mammals, in relation to body weight—would in itself place definite restrictions on the movements of these animals.

### *Body temperature and metabolism*

The variable body temperature of sloths has been noted by Kredel (1928). Wislocki (1933) also has discussed this subject from the viewpoint of intra-abdominal testicular function.

In recent studies (Britton and Atkinson, 1938) it has been pointed out that the average rectal, gastric, muscular, and cardiac temperatures in sloths are from 3° to 6° C. lower than in most mammalian types. The three-toed form showed the lower and more variable temperature. Exposure of sloths to moderately cold air (10° to 15°C.) resulted in a rapid loss of body heat. Within four to seven hours the rectal temperature was reduced to about 20°C., and a state of cold narcosis similar to a hibernating condition set in, without the occurrence of shivering. Recovery of normal temperature occurred on exposure to a warm atmosphere. In this connection it may be observed that sloths show very little abdominal and no subcutaneous fat deposits.

Sloths that were placed in ordinary direct sunshine in the tropics (35° to 40°C.) showed a sharp rise in rectal temperature to a lethal level (40°C.) in about two hours. Panting and other evidences of hyperthermia became extreme, and several animals succumbed from such experiences.

These observations, along with other unpublished data showing wide body temperature changes with diurnal fluctuations in air temperature, indicate that sloths possess a very limited thermoregulatory mechanism. Indeed, these animals, especially the three-toed form, may be considered as poikilothermic in character, since their body temperature varies in agreement with and only a few degrees above that of their surroundings. They are probably not far removed in this and some other respects from an ancient reptilian ancestry.

In captivity in large open-air pens in the tropics, sloths almost invariably seek the deepest shade during the warmer part

of the day, or from 10 A.M. to 4 P.M. In the depths of the jungle forest the air temperature is said to vary but little from 30°C. throughout the year, and here the sloth abounds. Its long, hairy coat and thick skin are highly insulatory, and considering also its sluggish mode of life in a relatively thermostable habitat, almost ideal conditions are present for maintaining a not-too-widely fluctuating body temperature with the least expenditure of energy.

From many aspects it appears that the metabolism of the sloth is extremely low. One report (Almeida and Fialho, 1924) states that in the case of *Bradypus tridactylus* the basal metabolic rate showed an output of 11 to 12 Cals. per square meter of body surface per hour, in striking contrast to the normal mammalian average of approximately 40 Cals. Thus its caloric output would seem to be only 25 or 30 per cent of that shown by most higher animal types. Besides further considerations involving low body temperature and general inactivity, the small amount of skeletal muscle tissue relative to body weight possessed by the sloth also is significant. The very large, complex gastric apparatus, amazingly tardy in function, would further contribute to the lethargic scheme of life.

It may be observed in connection with the above that sweat glands, as well as sebaceous glands, are said to be absent in *Cholepus* (Walter, 1928). They are present in large numbers on the snout, however, for the animal shows beads of perspiration here, but not on the footpads, when experimentally overheated. Moreover, Wislocki's careful work (1928) has shown that while in *Bradypus* the sweat glands are extremely small and infrequent, in *Cholepus* they are present all over the hairy portion of the body and nose. It can hardly be imagined, however, that sloths would ever need to eliminate heat rapidly by sweating, under normal conditions. They may nevertheless move sufficiently to raise their body temperature a degree or so, after long provocation (Britton and Kline, 1939), and exposure to direct tropical sunshine for a few hours may warm up an animal above normal; but these are quite abnormal conditions. In the event of hyperthermia, panting with mouth open and tongue out occurs, and thus some excess heat may be lost.

### *Carbohydrate metabolism*

Comment has already been made on the blood-sugar levels in sloths, which is fairly normal for mammals and averages about 85 mgs. per cent. Glycogen values in various tissues were found to average as follows: Two-toed sloth (10 cases): liver 0.50, muscle 0.42, and heart 0.48 per cent; three-toed sloth (13 cases): liver 0.54, muscle 0.47, and heart 0.61 per cent (Britton, Kline, and Silvette, 1938). These are rather low figures compared to those found in other mammals. In view of the fact that in all cases examined the animals were digesting carbohydrate materials (this was so even after several days of fasting), the liver glycogen levels appeared notably low. They were indeed less than 50 per cent of the mammalian normal. The small size of the liver in the sloth—about half that found in higher forms—may also be recalled in this connection. The conditions suggest functional limitations, although the rate of glycogen formation and liberation is an important consideration to be borne in mind. Several tests were made to determine the conditions present, with the following results.

Subcutaneous adrenalin injections in large amounts up to 1 cc. of 1:1000 solution, tested on both two-toed and three-

toed forms, resulted in only slight increases (10 or 15 per cent) in the blood-sugar level. Apparently glycogen reserves were not readily mobilizable.

Insulin administration was withstood rather poorly by both *Bradypus* and *Choloepus*, even in the non-fasting condition. Convulsions occurred in three to four hours with the smaller doses used, and none of the three-toed sloths recovered. In several instances the two-toed animals made good recovery, however, after showing profound depression for a day or so from a single dose of insulin.

Adrenalectomy resulted in death, usually within 24 hours, after marked losses (50 per cent or more) in blood sugar and liver glycogen. Important reductions were observed also in skeletal muscle and cardiac glycogen. This very rapid death after adrenal removal, correlated with severe losses in carbohydrate materials in the presence of large amounts of food in the gastro-intestinal tract, is again of considerable significance.

In all cases in which pancreatectomy was carried out, moderate hyperglycemia (200 to 300 mgs. per cent) developed, but not until three or four days had elapsed after operation. These and the foregoing results all point, therefore, to a slowly-acting, low-grade glycotaxic mechanism in the sloth.

### *The brain: decerebration*

It has been observed that the weight of the brain in sloths appears fairly high (see above), considering the animal's low scale of life. Sketches of the dorsal surface markings are given herewith (Fig. 19).

Reaction times in the tridactyl sloth have been found to be slower than in the didactyl form (Langworthy, 1935), in keeping with observations on general daily activity, herein noted. The flexor muscles are said to be anti-gravity in type, and extensor responses of the limbs on stimulation of cortical areas are found to be predominant. Several cortical motor areas were delimited by Langworthy, and the facial and other regions were notably more differentiated in the two-toed form.

From common observation, it is evident that responses to touch are prompt and well defined, and taste and smell are also well developed. Sight (by day) and hearing appear very limited in comparison with higher forms.

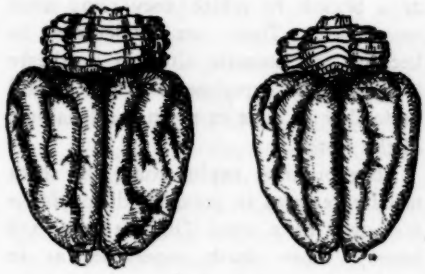


FIG. 19. THE BRAIN OF (A.) TWO-TOED AND (B.) THREE-TOED SLOTHS, SKETCHED FROM ABOVE

That of the two-toed form is somewhat more richly marked. Areas from which muscular responses have been produced on stimulation are similar to those in higher mammals.

Richter and Bartemeier (1926) have stated that decerebration in the sloth results in a flexor rigidity rather than an extensor condition as observed in other mammals. This was to be expected, these workers remarked, on the basis of the principle reached by Sherrington in his work on animals maintaining the upright posture. In our own experiments we have noted, however, the occurrence of both extensor and flexor rigidity in sloths after decerebration: in different animals the one or the other condition predominated. Also, flexion

was observed early after operation, while extension usually appeared later. These results will be discussed elsewhere (Britton and Kline, 1941).

*Operative procedures*

It should be emphasized that most operations on the sloth are withstood extremely well, and on many counts this animal is excellent for physiological studies. By approaching it from behind it may be taken and held fairly easily, although the limbs may have to be removed one at a time from the cage wall or a branch to which they cling most tenaciously. There are difficulties in keeping the animals alive in northerly latitudes, and experimental work should preferably be done in the natural habitat of the sloth.

After bilateral nephrectomy the sloth usually remains in good condition for a few days to a week (in one case, 176 hours), when death supervenes as in other forms with high blood urea values. Glycogen losses in skeletal muscle and liver are also marked. Thyroidectomy was non-fatal in one case observed, but activity was reduced even below the normal sloth level. Depancreatized animals survived for a week or more in good (but diabetic) condition. After extensive brain destruction or low decerebration, good responses were shown for several days.

Removal of the adrenals was the only operation studied which resulted in very rapid deterioration and death: in some cases the survivals were only 12 hours, and the average of all cases was 26 hours. The operation itself was very simple, and symptoms and deaths were typical. It is therefore clear that sloths are greatly dependent on proper adrenal function for even their very leisurely pace of living. How much more then, may we say, are higher mammals with their comparatively terrific living tempos dependent on the normal functioning of the adrenal mechanism.

THE SLOTH'S SLUGGISHNESS

There are a number of anatomical and physiological features of the sloth which tend to make it the slowest of all living mammals. In this connection the following points may be summarized briefly from the foregoing discussion:

Sloths possess a relatively small amount of skeletal muscle tissue, all of it being of the slowly-reacting (red) type and possessing a physiologically low-grade, low-pressure blood supply.

There is a very small respiratory (pulmonary alveolar) surface, and a large dead space (three-toed animals).

A small heart, and small thyroid and adrenal glands, are present.

The liver is small in size and shows low glycogen reserves, and functional tests indicate very limited carbo-metabolic abilities.

The stomach and rectum with their contents are very ponderous, and the rate of digestion and absorption is extremely slow.

The skin is almost inelastic, and there is a heavy coat of hair.

There is a poorly-developed sense of equilibrium, and the reflexes are slow.

The body temperature and basal metabolism are relatively much lower than in other animals.

Although many other conditions are probably also involved, the above constitute a striking list of restrictions and embarrassments to an active life. It is interesting to observe that an efficient means for even further depressing sloth activity is found in the well-developed vagus nerves, which on coming into play may reduce cardiac rate (and thus affect

circulatory and general body conditions) to 10 per cent only of its normal level. On adequate stimulation the sympathico-adrenal mechanism may on the other hand bring about greatly heightened circulatory and muscular responses, which may even approximate some of those observed in the higher mammals.

### *On deslothing the sloth*

Several ways of speeding up the sloth from its (anthropomorphically-considered) sluggardy have been noted (Britton and Kline, 1939). The rate of travel along the under side of a 12-foot horizontal pole, timed by stopwatch, was used as a test. To this the sloth became readily accustomed.

Raising the temperature of the animal appeared to be the best stimulator. Mere exposure to the tropical sun for a short while, resulting in elevation of the body temperature a few degrees, augmented activity on the average 50 per cent, and in some cases over 100 per cent. Again, setting up an emotional reaction in the sloth, by simple feints and passes before it, increased its speed markedly. The administration of various substances, such as adrenalin, prostigmin and cortico-adrenal extract, also provided an adequate stimulus to increased activity. Cortico-adrenal extract appeared to maintain the increased rate of upside-down travel by the sloth for 10 or 12 hours after injection, in keeping with earlier observations on the dog (Eagle, Britton and Kline, 1932). Prostigmin as well as emotional stimulation brought out the fighting instinct, along with the greater ability to "run" away.

The rate of progress of the sloth may be determined approximately from our data on a mileage basis. It appeared from several hundred tests (Britton and Kline, 1939) that the two-toed sloth normally averaged a little over three hours to the mile, and three-toed animals almost four-and-a-half hours. The slowest individual tardigrades, however, took over six hours for the distance. Under excitation such as that noted above, the mile was possible in about two hours, and in a burst of speed by one animal only, a mile an hour was accomplished. In a few comparative tests, turtles and tortoises were observed to travel at about the same rate as sloths.

When placed on a smooth plane surface the sloth is unable to move forward, but in the grass or on earth it pulls itself along by dint of clinging with its claws. It is likely that in the wild the higher rates of progress indicated above would not obtain, because of difficulties of arboreal travel, lack of maximal stimulus, etc. Fatigue over stretches of a hundred feet or so would also be an important restricting factor, as indicated by the poor condition of animals after 8 or 10 tests on the 12-foot bar. Several fairly effective methods of deslothing the sloth may however be employed, at least to the extent herein described.

It may be questioned whether even a modicum that is praiseworthy attaches to such excitatory tactics practised on the humble sloth. Yet it does appear to be in the nature of man to ever cast about for new stimulants or anti-inhibitants, for himself and his friends, and some observers are driven to test such substances on the animals about them. Fast pacers and night lifers might with profit take a tip from the sloth now and then, however, and consider its ways and perhaps be wise. It may be that a potent sloth extract (extractum tardigradi!) would serve a more useful purpose in many ways than excitants, in this present headlong-charging world

The writer is grateful to Dr. H. E. Anthony of the Museum of Natural History, New York, to Dr. G. S. Miller, Jr., of the Smithsonian Institution, Washington, and Dr. R. K. Enders, of Swarthmore College, for some evidence regarding the limits of distribution of sloths. Dr. A. O. Foster and Dr. G. B. Fairchild of the Gorgas Memorial Laboratory have identified a number of sloth ticks, worms and moths, and to these workers I am also indebted for much information. Mr. J. B. Shropshire, a delightfully keen amateur naturalist of the Canal Zone, supplied considerable data on sloth habits, and through his splendid organizing ability many sloth hunts were arranged and most of our experimental supplies secured.

## LIST OF LITERATURE

ALMEIDA, A. O., and B. DE A. FIALHO. 1924. Métabolisme, température et quelques autres déterminations physiologiques faites sur le paresseux (*Bradypus tridactylus*). *Comp. rend. soc. de biol.*, 91: 1124–1126.

DE ALMEIDA, M. O. 1928 Sur la régulation nerveuse de la respiration chez le Paresseux (*Bradypus tridactylus*). *Comp. rend. soc. de biol.*, 98: 1573–1574.

——. 1928. Sur la régulation chimique de la respiration chez le Paresseux (*Bradypus tridactylus*). *Ibid.*, 98: 1576–1578.

ATHILL, L. 1937. Marginal comments. *Spectator*, 158: 514.

BEEBE, W. 1925. Studies of a tropical jungle. *Zoologica*, 6: 5–193.

——. 1926. The three-toed sloth, *Bradypus cucullinger cucullinger Wagler*. *Zoologica*, 7: 1–67.

——. 1938. Personal communication.

BLUME, W. 1928. Über den Verlauf der Luftröhre bei *Bradypus tridactylus*. *Anat. Anz.*, 65: 230–232.

BRITTON, S. W., and W. E. ATKINSON. 1938. Poikilothermism in the sloth. *Jour. Mammal.*, 19: 94–99.

——, and R. F. KLINE. 1939. On deslothing the sloth. *Science*, 90: 16–17.

——, and ——. 1939. Emotional hyperglycemia and hyperthermia in tropical mammals and reptiles. *Amer. Jour. Physiol.*, 125: 730–734.

——, and ——. 1941. In preparation for press.

——, ——, and H. SILVETTE. 1938. Blood-chemical and other conditions in normal and adrenalectomized sloths. *Amer. Jour. Physiol.*, 123: 701–704.

BROMAN, I. 1929. Über die angeblich "einzig deste enden" Mesogastrien und Leberligamente bei den Faultieren. *Verhandl. Anat. Ges.*, 38: 58–63.

BUFFON, G. L. LEC. DE. 1766. Histoire Naturelle: Quadrupèdes. 26: 47.

DE BURLET, H. M. 1911. Über die äusseren Formverhältnisse der Leber der Faultiere. *Morph. Jahrb.*, Bd. 43, S. 477.

COBBERGH, H. 1930. Das Organ von Ackerknecht bei Bradypodidae. *Anat. Anz.*, 69: 12–18.

CUVIER, BARON. 1837. The Animal Kingdom. *London*, 1: 140.

DAMPIER, W. 1717. A New Voyage Round the World. *London*, Vol. 2.

EAGLE, E., S. W. BRITTON, and R. F. KLINE. 1932. The influence of cortico-adrenal extract on energy output. *Amer. Jour. Physiol.*, 102: 707–713.

EXQUEMELIN, O. A. 1678. De Americaensche Zee-Roovers. *Amsterdam*.

FLOWER, W. H. 1882. On the mutual affinities of the animals composing the order Edentata. *Proc. Zool. Soc.*, p. 358.

GOLDSMITH, OLIVER. 1825. A History of the Earth and Animated Nature. *New York*, p. 442.

GREW, NEHEMIAH. 1681. Musaeum Regalis Societatis; or A Catalogue and Description of the Rarities Belonging to the Royal Society, and Preserved at Gresham College. I., II.

HEGNER, E., and E. SCHUMAKER. 1928. Some intestinal amoebae and flagellates from the chimpanzee, three-toed sloth, sheep and guinea-pig. *Jour. Parasit.*, 15: 31–37.

HEUSER, C. H., and G. B. WISLOCKI. 1935. Early development of the sloth (*Bradypus griseus*) and its similarity to that of man. *Pub. Carn. Inst. Wash.* 459: 1–13.

HOWELL, A. BRAZIER. 1930. Aquatic Mammals.

JUAN, DON G., and DE ULLOA, DON A. 1748. Relacion historica del viage a la America. Tome prim., Cap. V., 135–137.

KAHN, M. C. 1931. Djuka, the Bush Negroes of Dutch Guiana. *New York*. p. 151.

KREDEL, F. E. 1928. Note on the temperature of the sloth. *Jour. Mammal.* 9: 48.

LANGWORTHY, O. R. 1935. A physiological study of the cerebral motor cortex and the control of posture in the sloth. *Jour. Comp. Neur.*, 62: 333–348.

MILLER, G. S. JR. 1939. Private communication.

MILLER, R. A. 1935. Functional adaptations in the fore-limb of the sloth. *Jour. Mammal.*, 16: 38–51.

Oria, J. 1929. Histiocytos livres no sangue circulante de varias especies brasileiras de mammiferos sylvestres. *Ann. Fac. Med. Sao Paulo*, 4: 39–48.

Oviedo y Valdés G. F. de. 1526. De La Natural Historia de las Indias: Perico Lijero. Chapter 24, folio 22 (Colophon: "*Toledo*, 1526").

Pennant, T. 1771. Synopsis of Quadrupeds. *Chester* (*England*).

Purchase, Samuel. 1613. Pilgrimage. P. 704, note.

Richter, C. P., and L. H. Bartemeier. 1926. Decerebrate rigidity of the sloth. *Brain*, 49: 207–225.

Straus, W. L. Jr. 1937. Cervical ribs in the woolly monkey. *Jour. Mammal.*, 18: 241–242.

Tevis, M. 1925. An animal hanging basket. *Mentor*, 13: 58.

Turner, W. 1873. On the placentation of the sloths. *Trans. Roy. Soc. Edin.*, 27: 71–104.

Walter, H. E. 1928. Biology of the Vertebrates. *New York.*

Weber, M. 1904. Die Säugetiere. *Jena.*

Wislocki, G. B. 1927. On the placentation of the tridactyl sloth. *Contribs. to Embry., Carn. Inst. Wash.*, No. 380: 209–228.

——. 1928. Observations on the gross and microscopic anatomy of the sloths (*Bradypus griseus griseus* Gray and *Choloepus hoffmanni* Peters). *Jour. Morph. and Physiol.* 46: 317–397.

——. 1933. Location of the testes and body temperature in mammals. Quart. Rev. Biol., 8: 385–396.

——. 1938. The topography of the hypophysis in the *Xenarthra*. Anat. Rec., 70: 451–463.

—, and W. L. Straus, Jr. 1932. On the blood vascular bundles in the limbs of certain edentates and lemurs. *Bull. Mus. Comp. Zool.*, 74: 1–15.

# NEW BIOLOGICAL BOOKS

*The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that* THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Maud deWitt Pearl, Assistant Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *401 Hawthorn Road, Baltimore, Maryland, U. S. A.*

## BRIEF NOTICES

### EVOLUTION

THE MAMMALIAN FAUNA OF THE WHITE RIVER OLIGOCENE. *Part II. Rodentia, by Albert E. Wood. Part III. Lagomorpha, by Albert E. Wood. Part IV. Artiodactyla, by William B. Scott. Transactions of the American Philosophical Society held at Philadelphia for Promoting Useful Knowledge. New Series, Volume XXVIII, Parts II, III, and IV.*

*By William B. Scott and Glenn L. Jepsen. American Philosophical Society, Philadelphia.* Part II, $2.00; Part III, $1.00; Part IV; $2.50. 11¾ x 9; Part II, 155–269 + 11 plates; Part III, 271–362 + 2 plates; Part IV, 363–746 + 44 plates; Part II, 1937; Parts III and IV, 1940 (paper).

The strata of the White River oligocene have been for nearly 100 years the "happy hunting-grounds" of the palaeontologist. Early findings were entrusted to the care of Dr. Joseph Leidy who laid the foundation and gave impetus to the fine quality of work that American palaeontologists have produced. Later, Cope and Marsh developed the collecting of fossil forms to a fine art. Today, many museums are the repositories for the remarkable treasures that were stored so long ago in the White River beds. Leidy, in 1865, listed 14 families and 19 genera as representing the mammalian fauna. Scott in his preface to the Monograph of the White River fauna (cf. Q.R.B., Vol. 12, p. 90 for mention of Part I) lists 35 families and 98 genera of mammalian forms—"yet the 'novelties' continue to come in." In Part II of this series (issued in 1937) Wood has increased Scott's list somewhat by his study on the rodents.

In Part III, Wood comes to the conclusion that the lagomorphs (rabbit-like forms) are of a "very ancient mammalian stock, presumably Eutherian, which has evolved, at a slow rate, as an entirely independent line at least since the Paleocene and perhaps since the Mesozoic." There are indications that "for some reason the lagomorphs are a very stable group, genetically, so that mutations of a specializing type take place relatively rarely."

Scott, in Part IV, considers the White River artiodactyls a very ancient and primitive assemblage with but two of the nine families having any descendants in the modern world. One of the striking features is the entire absence of the Pecora. Scott believes that "the Tylopoda took the place of the Pecora and played the role that the latter did in the Old World . . . Of the families included in the Tylopoda, one, the Camelidae, is not questioned by any one and, in the White River genera, there is every reason to think, we have the actual ancestors of all existing camels and llamas."

These studies are enriched by tables of measurements, finely executed text-figures and plates.

THE COURSE OF EVOLUTION *by Differentiation or Divergent Mutation rather than by Selection.*

*By J. C. Willis. The University Press, Cambridge; Macmillan Company, New York.* $3.00. 8½ x 5½; viii + 207; 1940.

The ideas propounded by Willis in 1922 in his famous work on age and area have had a great influence on the thinking of the younger generation of biologists. If his views have not been universally accepted *in toto*, the explanation lies in the usual reticence to discard any well-established theory, particularly one that has become literally an article of faith for modern scientists, such as, for example, Darwin's concept of natural selection. Moreover, it is to be admitted that as plausible as Willis's theory is—that evolution results not from natural selection of chance variations but from single mutations which cause structural alterations, and that it proceeds from family to variety—full and final proof of its validity has not yet been given. Additional evidence to support the author's contention is presented in the present volume which constitutes a logical sequence to the earlier work. The author first traces the evolution of his own concepts on the subject of natural selection and describes the kinds of observations that finally led him to the formulation of his theory. He proceeds then to present 34 sets of observations involving frequency of genera, morphology, taxonomy, and geographic distribution. He compares the interpretation of such observations in terms of natural selection and of age and area, respectively, and presents a convincing case for the latter. In the brief space allotted, it is hardly possible to consider adequately the author's discussion. This book, as its predecessor, deserves careful study and will without doubt be the source of a revaluation of current views.

GENES AND GENESIS. *Ministerial Reading Course Selection for 1941.*

*By Harold W. Clark. Pacific Press Publishing Assn., Mountain View, Calif.* $1.50. 7¾ x 5⅛; 155; 1940.

Now that the classical Darwinian theory of evolution has been modified by the recent discoveries in genetics it seems that there are only a few minor points that separate the fundamentalist from the natural philosopher. These are expressed by the fundamentalist belief that God created the world in six calendar days. There is nothing, the author asserts, in biology to contradict such beliefs. The arguments used to support this view are not new but the author has brought them up to date by making good use of recent developments. It is well to note that this book is the 1941 selection of the Seventh Day Adventists Ministerial Association. We hope that the ministers will really read it for it is impressive because of the uncommon erudition and dialectic abilities of the author.

STUDIES OF CENOZOIC VERTEBRATES AND STRATIGRAPHY OF WESTERN NORTH AMERICA. *Contributions to Paleontology. Publication No. 514.*

*By Paul C. Henshaw, Robert W. Wilson, Hildegarde Howard, Alden H. Miller, Jack F. Dougherty and Richard H. Jahns. Carnegie Institution of Washington, Washington, D. C.* $2.75 (paper); $3.25 (cloth). 10 x 6¾; iii + 194 + 24 plates + 1 folding map; 1940.

This contribution includes nine studies on the fauna of the Cenozoic from various parts of western North America, eight of which concern mammal remains. The ninth shows the avifauna of Rancho La Brea to be between typical Pleistocene and the typical Recent. Among the faunal lists are descriptions of new species and redescriptions of poorly preserved material, especially that of *Paratylopus cameloides*. There is also a contribution to the stratigraphy of the easternmost Ventura Basin, a description of a new mammalian fauna from Caliente Mountain, studies on the Paramyid rodents and *Pareumys* remains of California, and the mammalian fauna of the Avawatz Mountains. Relationships and correlations are discussed in all these studies.

SOME FOSSIL PLANT TYPES OF ILLINOIS. *A Restudy of the Lesquereux Types in the Worthen Collection of the Illinois State Museum, Augmented by Descriptions of New Species from Mazon Creek. State of Illinois, Department of Registration and Education. Scientific Papers Vol. I.*

*By Raymond E. Janssen. Illinois State Museum, Springfield.* $1.25. 10 x 6¾; xv + 123; 1940 (paper).

The first descriptions of Illinois plant fossils were made in 1866 and 1870 by the paleontologist Lesquereux. He found 109 new species in various localities in the state. Recently 59 of his type specimens have been brought to light and have been restudied and reclassified. The first part of this report deals with the Lesquereux material. Illustrations of his type specimens are shown in 24 photographic plates. In the second part, ten new species and varieties of fossil plant impressions from the Mazon Creek region are described and illustrated. An eleven-page bibliography and an index of species names completes the study.

ON ONE OF THE LEAST KNOWN OF THE CLEVELAND SHALE ARTHRODIRA. *Scientific Publications of the Cleveland Museum of Natural History, Vol. VIII, No. 3.*

*By David H. Dunkle and Peter A. Bungart. Cleveland Museum of Natural History, Cleveland.* 9¼ x 6¼; 19 + 2 plates (paper).

## GENETICS

ANIMAL BREEDING. *Third Edition.*

*By Laurence M. Winters. John Wiley and Sons, New York; Chapman and Hall, London.* $3.50. 9 x 6; viii + 316; 1940.

This book has been thoroughly revised to present the newer knowledge of scientific breeding gained from recent experience and experimentation. The net income realized on livestock is in direct proportion to the merit of the stock, and high merit can be attained only by an understanding of the biological principles involved in breeding. With this in mind the author first describes reproductive anatomy, the hormonal control over breeding cycles, the fundamental genetic basis of animal breeding, and detailed procedures for artificial fertilization. The second half of the volume is devoted to the methods used for improving stocks and maintaining them at a high level. This includes purebred breeding, grading, inbreeding, crossbreeding, and community breeding. Not only are numerous examples given as to the efficacy of methods practiced upon domestic animals, but the text also contains reviews of experiments which have already found practical application, and others which hold promise for the future. Animal husbandry has before it the task of devising more adequate measurements of quality and of increasing the use of artificial insemination, proved sires, and records of performance. In addition to its unquestionable value to the breeding industry this book will prove useful in pointing out to animal biologists the fields where research is most demanded. The text is amply illustrated and contains a bibliography of over 400 titles.

AN EXPERIMENT IN THE TEACHING OF GENETICS *with Special Reference to the Objectives of General Education.*

*By Austin DeM. Bond. Bureau of Publications, Teachers College, Columbia University, New York.* $1.85. 9 x 6; viii + 99; 1940.

Present day pedagogy stresses teaching the social aspects rather than the systematic foundations of science. The interesting observations reported here bear on the validity of such a viewpoint. Two groups of college freshmen were taught genetics, but in a different manner. For one group, the control, the orthodox textbook exposition was followed. In teaching the other group, the experimental, the question of race differences was especially emphasized. The main results are that in the end the control group demonstrated better knowledge of the mechanics of genetics while the experimental group possessed clearer ideas about

racial problems. These results could have been foreseen but they reinforce the well-known concepts that knowledge of the fundamentals of a science is not sufficient to allow for their general application and that the teacher's viewpoint influences that of the pupil. It will be some time before the new pedagogic technique becomes generally applied and until the final effects are evident it is not proper to prejudge them.

MULTIPLE HUMAN BIRTHS. *Twins, Triplets, Quadruplets and Quintuplets.*

*By H. H. Newman. Doubleday, Doran and Company, New York.* $2.50. 8¼ x 5⅛; xii + 214; 1940.

This is the first of a non-technical series of texts published under the auspices of the American Association for the Advancement of Science. Since the book is directed at the general public, Newman has purposely restricted his field of discourse to topics that excite popular interest, as well as misconceptions. He discusses the causes, frequency, and kinds of twins and other multiple births; psychologic traits of and criminality in twins; the scope of studies on twins in relation to the nature-nurture problem. A chapter is devoted to the Dionne quintuplets, and in two other chapters are summarized the results of the well-known investigations of the author and his associates. An excellent list of references is included. As would be expected, the book reflects Newman's authority on the subject. However, this attempt at popular science writing cannot be considered too successful from the standpoint of readability.

PRINCIPLES OF GENETICS.

*By E. Grace White. C. V. Mosby Co., St. Louis, Mo.* $2.50. 8½ x 5½; 352; 1940.

The material and scope of this text is much the same as that of several other recent books in the field of genetics, although less technical than some. In addition to the fundamental discussions of Mendelism, animal breeding, measurement of variation, and eugenics, there are reviews of the most recent work on the nature of the gene and hormone influence. Although the volume is written in a clear and interesting manner, it lacks a critical attitude toward certain studies on which there has been a difference of opinion, particularly in the section concerning human heredity. On the other hand, the writer rightfully discusses the present status of the gene with reservation. The book can well be used in the classroom since its arrangement is orderly, it contains a good topical reference list, and possesses an adequate index.

## GENERAL BIOLOGY

FOOD PRODUCTION IN WESTERN EUROPE. *An Economic Survey of Agriculture in Six Countries. Being the Report of an Inquiry organized by Viscount Astor and B. Seebohm Rowntree.*

*By P. Lamartine Yates. Foreword by Sir William Beveridge. Longmans, Green and Co., London, New York and Toronto.* $6.00. 9⅜ x 6½; xv + 572 + 16 plates; 1940.

From 1934 to 1938, series of inquiries into the farming situation in Great Britain were organized by Viscount Astor and B. S. Rowntree. In the course of these investigations it became apparent that the agricultural experience of some neighboring countries in Western Europe, which have a somewhat similar climate to that of Great Britain, might yield some items of great value for the formulation of an agricultural policy in the latter country. Mr. Yates was commissioned to make an intensive study of the conduct of agricultural pursuits in Denmark, Holland, Belgium, France, Switzerland, and Germany. This book, presenting his findings, deals not only with the type of holdings, type of farming (live-stock, dairy, or plant production), proportion of population engaged in agriculture, capital and income of the farm population, land reclamation, cost of food products, etc., but also with market boards, co-operatives, quota systems, and other measures

of control which have grown up in recent years. Each country is considered separately, and in concluding chapters comparisons are made between the agricultural systems and policies of these countries with each other and with Great Britain. The study was concluded before the outbreak of World War II, and the suggestions for future policies will no doubt need revision before the opportunity is presented to put them into effect.

The book is well documented, illustrated with photographs, and there is an index.

ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION: *Showing the Operations, Expenditures, and Condition of the Institution for the Year Ending June 30, 1939. Publication 3555.*

*Smithsonian Institution. U. S. Government Printing Office, Washington.* $1.50. 9 x 5¾; xiii + 567 + 138 plates; 1940.

From a very early date in its history it has been the custom of the Board of Regents of the Smithsonian Institution to enrich its annual report with interesting papers published during the year, which show the more important developments in scientific discovery. The present report is no exception. We regret, as usual, that the limited space in these columns precludes an adequate review, or even a complete list, of the 27 outstanding contributions. The papers of primary interest to biologists include: Humanity in geological perspective, by H. L. Hawkins; Biologic balance on the farm, by W. L. McAtee; On the frontier of British Guiana and Brazil, by H. C. Smith; The sea bird as an individual: results of ringing experiments, by R. M. Lockley (the observations were made at Skockholm Island); Birds and the wind by N. T. McMillan, Captain, Eastern Air Lines (a provocative study refuting some of the ideas accepted by ornithologists concerning the flight and migration of birds); The problem of conserving rare native plants, by M. L. Fernald (he discusses also the introduced exotic plants whose spread has reached weed proportions, thereby crowding out native plants); Plankton in the water supply, by Florence E. Meier; and several papers of archaeological and ethnological interest. The articles are liberally illustrated with drawings, photographs, or both, and most of them are provided with bibliographies.

LOOK TO THE LAND.

*By Lord Northbourne. J. M. Dent and Sons, London.* 7s. 6d. net. 7¼ x 4¾; v + 206; 1940.

The author believes that many of the economic problems of the present day are conditioned fundamentally by the diseased "biological state" of the world, that is, by the condition of the soil and the conduct of agricultural pursuits. The extent of desert formation has been enormously accelerated in comparatively recent times in the "dust bowls" of the United States, in Australia and Russia which run close to the United States' record in this respect, in Africa, and to a less noticeable but not negligible degree in Europe. This and many other processes of erosion and depletion of once fertile soil the author blames largely on modern farming methods and misdirected research (mass production, specialization of crops or type farming, overstocking in some cases and understocking in others, exclusive use of artificial fertilizers, etc.). He considers also the financial, commercial and sociologic aspects of the problem to the conclusion that a return to the mixed type, self-sufficient farm, with a large, healthy manure pile, and with as little interference from the government as possible, is highly desirable.

The higher the degree of biological self-sufficiency achieved by a farm, a district, or a nation, the more alive, the more vigorous, and the more creative it will be, and the *more* it will have to exchange with its neighbours, not the less.

Lord Northbourne has a large mixed farm and several market gardens in England, and is actively interested in agricultural education.

A selected bibliography of non-technical works and an index are provided.

MAN AND THE LIVING WORLD.

*By E. E. Stanford. The Macmillan Co., New York.* $3.50. 8½ x 5½; xxviii + 961; 1940.

The task of organizing a text for use in the increasingly popular college survey courses in biology is an enormous one, made all the more difficult by the fact that most of these courses are crowded into one semester, and are entirely devoid of any laboratory or field work. Stanford's text is well adapted for just such a course, and presents a program of such scope and variety as to accommodate the needs of widely divergent types of classes and schools. The method of organizing the material into units is an excellent one, making for ease of selection, and resulting in a well-rounded course when the limits of time require that only part of the total field be covered. The textual material is authoritative, well documented, and extremely comprehensive, the latter fact being made clear by ten unit titles, some of which we list: Science and living things; The green plant, manufacturer of foodstuffs and of raw materials for industry; The human body, its structure and functions; Microorganisms and their relation to human life; Domestication and breeding of plants and animals; The biological resources of the United States and their utilization.

The text is supplied with an abundance of illustrative material and a comprehensive index.

BIOLOGY IN THE MAKING.

*By Emily E. Snyder. McGraw-Hill Book Company, New York and London.* $2.80. 8 x 5⅜; xii + 539; 1940.

It is for readers without a scientific background, that this book is written. The author's purpose is "to trace the development of biological discoveries, not as so many facts, but as the product of real men whose lives for one reason or another made them outstanding in their fields." There are several appendices, a chronological table listing the major contributions of the 125 scientists whose works have been discussed, a glossary, a bibliography, and an index.

THIS AMAZING PLANET.

*By Roy Chapman Andrews. G. P. Putnam's Sons, New York.* $2.00. 7¾ x 5½; ix + 231; 1940.

In *This Weeks Magazine* there has appeared from time to time a series of articles under the general title *This Amazing Planet*. Prepared by the Director of the American Museum of Natural History for popular consumption, they dealt with little-known facts of natural history, prehistoric life, and observations of uncommon behavior of familiar animals, which the author had jotted down on his world-wide travels. These articles, 80 in number, are here made available in book form.

## HUMAN BIOLOGY

JOHN AND WILLIAM BARTRAM, *Botanists and Explorers, 1699–1777, 1739–1823.*

*By Ernest Earnest. University of Pennsylvania Press, Philadelphia.* $2.00. 8 x 5½; vi + 187; 1940.

This is a biographical essay dealing with two of the more significant figures in American history. Together the lives of the Bartrams, father and son, covered all the eighteenth century and overlapped the seventeenth and nineteenth.

It is a remarkable fact that a man of so little education that he never learned to spell correctly, should have eventually achieved such a pinnacle of eminence that Linnaeus considered him to be the greatest living natural botanist—yet such is the case. To account for this the author has gone deeply into the early environment of John Bartram, and finds that many of the leading intellects of the New World, such as James Logan, Isaac Norris, and Francis Daniel Pastorius, (all of whom were botanists as well as statesmen) were instrumental in shaping Bartram's character. Also, he tells us of numerous botanical gardens in the colonies that antedated Bartram's Arboretum, notably that of Kelpin's, established in 1694 (incidentally, why do we read so little about this picturesque prophet of the frontier?).

It was Logan who was influential in sending the older Bartram to Onondaga in 1743 with Lewis Evans the cartographer

and Conrad Weiser, the interpreter, whose parents were Palatinate refugees, but who was born in America and brought up as a member of the Maqua Indian tribe. The object of this expedition was to make peace between the six nations and some Virginia backwoodsmen. This was the beginning of John Bartram's travels in the colonies and Florida to gather botanical material.

But it was Peter Collinson, the president of the Linnean Society of London, who did most to bring about Bartram's recognition by the scientific world. It was Collinson's mediation that won for Bartram the appointment of Botanist to the King, that induced the other crowned heads of Europe to apply to him for American plants, and that caused all European scholars visiting the colonies to call sooner or later at the Bartram residence.

William Bartram differed in many ways from his father. John believed that the only good Indian was a dead Indian and it was fear of the aborigines (whom he believed to be cannibals) that restricted his travels to the piedmont plateau. On the other hand, William preferred the red man to the white, judging him to have a higher sense of morality and honesty, and he even became initiated into an Indian tribe. Also he had the benefit of the education that his father lacked. He was familiar with the best English literature of his day, particularly with Pope's *Essay on Man*, and his prose journal exhibits such poetic qualities that it was a favorite of Coleridge and Wordsworth, many of whose works show such a striking parallelism of thought to those of Bartram that the author concludes that "Kublai Khan" and "Ruth" might not have been written had not Bartram's *Travels* pointed the way. To appreciate the influence that Bartram may have had on these poets, or on the later naturalists, such as Wilson, Say, and Nuttall one must read this book carefully.

The work is not perfect, however. The consistent misspelling of Ann Mendenhall's name, the use of such an ungrammatical construction as "one genera" and the failure to take into consideration the eleven days disagreement between the Julian and Gregorian calendars in fixing the birth date of the older Bartram are evidences of slipshod work. A more serious omission is that of all reference to John Bartram's sense of humor. Evidence of this trait of character occurs in the journal of Peter Kalm. It is impossible to read how the Swedish traveler tasted a green persimmon, expressed the juice of *Rhus toxicodendron* between his palms, or threw a club at a skunk to see whether these organisms would really react as Bartram said they would, without getting light on one side of the botanist's character that this book completely overlooks.

A more comprehensive and detailed index would have added to the usefulness of the work.

THE MONGOL EMPIRE: *Its Rise and Legacy. By Michael Prawdin. Translated by Eden and Cedar Paul. The Macmillan Co., New York.* $5.00. 8½ x 5½; 581; 1940. A book of absorbing interest. The author has drawn upon his imagination in order to create a continuous and vivid story, yet the substantiation of the main historical facts by chronological tables, a lengthy bibliography, maps, and other data testify to the extensive researches that he has made.

The welding together of the nomadic tribes of Asia into a powerful empire, the extension of that empire into Manchuria, China, India, Asia Minor, and eastern Europe to become the widest empire of all times, all this within a few years and through the great military genius of one man, is a fantastic and almost incredible story. The messenger and spy service, organized in great detail by Jenghiz Khan, had an important part in maintaining his power over the Mongols as well as over the neighboring countries. An "arrow messenger" was regarded as sacred. "The highest prince in the land made room for him to pass when the sound of his horse's bells was heard; and when his mount grew tired, the best available horse had to be supplied." With head and body bandaged to help him endure the long

ride by day and night he rode across steppes and desert "crossing in a few days distances which usually needed weeks to cover." Jenghiz Khan established the framework of a militaristic state where every man enrolled for war or for peace. During times of peace, the hunt, as practised by Mongolians, was simply a training for war, being military in all its phases.

The history of the disintegration of the great Mongolian Empire is even more interesting than its rise to power. In fading away it left its influence in all countries that it had dominated. Particularly was this true of Russia. A descendant of the Khan of the Golden Horde, one of the great Mongolian tribes, became Grand Prince of all Russia, and Tartar nobles intermarried with Russian aristocracy. The easy acquisition by Russia of all northern Asia was the natural outgrowth of this mingling of Russian and Mongolian peoples. Towards the end of the 16th century Cossacks, adventurers, and peasants migrated into the vast plains of Asia to make their homes among the Mongols.

For those desiring a clearer understanding of the historical foundations of eastern Europe and Asia we strongly recommend this book. It elucidates many of the present-day conflicts in the Eurasian setting. A useful index has been provided.

THE TRAGEDY OF GERMAN-AMERICA. *The Germans in the United States of America during the Nineteenth Century—and After. By John A. Hawgood. G. P. Putnam's Sons, New York and London.* $3.00. 8½ x 5½; xviii + 334; 1940.

The author, professor of History at the University of Birmingham, has studied the German-American problem for a number of years and spent 18 months in the United States under a Fellowship of the Rockefeller Foundation to do research in the field. The book is divided into three parts: The German as a settler in the United States; New Germanies on American soil; and The significance of the hyphen in German-American history.

Omitting the very early German immigrants and their descendants (this includes the Pennsylvania "Dutch") and those of the past 50 years or so, this scholarly study follows in the main the three classic divisions of German immigration, first outlined by Friedrich Münch: (1) The "German" period from 1815 to about 1855 during which time numerous unsuccessful attempts at founding New Germanies (mostly rural communities) on this continent were made, notably in Wisconsin, Missouri, Illinois and Texas; (2) the period from 1855 to 1870, when the 1848ers, mainly political exiles, realizing that their "cause" in Germany would not succeed and that they therefore would be permanently exiled, turned from old-worldliness, utopian ideas and a passive non-cooperation in American affairs to active participation in political, educational, and journalistic activities in this country. Their opposition to the "No Nothing Party," the Sabbatarian, Prohibition, and, particularly to the Nativism movements (also in some states to slavery) did not add to their popularity and made assimilation difficult. The hyphenated term *German-American*, originated in the early 50's, stuck through (3) the period from 1870 to about 1890, which was characterized by emigrants who left their native land to better their economic conditions, up to the entrance of the United States into World War I.

This is an important sociological study. Many of the 232 items in the bibliography are supplied with notes on their content and viewpoint. There is an index.

MY VANISHED AFRICA. *By Peter W. Rainier. Yale University Press, New Haven.* $2.75. 8 x 5½; viii + 307; 1940.

The author, who was born in Swaziland, South Africa, and is the great-great-grandson of the British admiral after whom Mount Rainier was named, has written the story of his life in Africa, a story that rivals the lustiest of Jack London's adventure novels. Peter Rainier's autobiography is the story of a

seasoned South African adventurer on the lookout for gold, diamonds, ivory, and more adventure; it is the story of a man who knows his country, its resources, and its people. Born in a tent in Swaziland, the author spent part of his childhood in an ox wagon, entering a British school in Natal at the age of nine. This latter proved an irksome thing to a boy who had been permitted by the old Zulu Chief Umfogazana to sit in the ceremonial circle and partake of beer—pleasures extended by Zulu custom only to adults. The Boer War, which was carried on close enough to the classroom to make things interesting, was the only event that saved him from complete boredom during this period. At sixteen he served under Duncan Mackenzie in the Zulu rebellion which took place after the death of the White Queen (Queen Victoria). After that Peter Rainier took Africa in his stride. He searched for diamonds in the Namib desert; went hunting with the Elephant Man, Chris Human; prospected on the Ruenya River, tributary of the Zambezi, for gold; searched in vain for the buried treasure of King Gungunyana; dredged on the Revue River for King Solomon's gold; joined Demilion's troop of scouts in the German Southwest African campaign in 1914; took part in an epic march in which General Duncan Mackenzie led his men on a 300-mile ride in seven days, on one day's rations, to defeat the Germans at Gibeon; was ordered by the Essential Industries Board to Mozambique to speed gold production on the Revue dredge and then to Nigeria for the remainder of the war to construct and operate two tin dredges on the Ropp Tin Mine, Bauchi plateau, where he tamed the Bauchi cannibals for mine work. Then in 1919, he departed, at the ripe age of twenty-nine, for more adventure in the Americas.

There are four text maps as well as maps on the end-papers. A glossary and an index are included.

THE MINGLING OF THE CANADIAN AND AMERICAN PEOPLES. *Volume I. Historical. A Series of Studies Prepared under the Direction of the Carnegie Endowment for International Peace, Division of Economics and History. By the Late Marcus Lee Hansen. Completed and Prepared for Publication by John B. Brebner. Yale University Press, New Haven; Ryerson Press, Toronto; Oxford University Press, London.* $3.00. 9⅛ x 6½; xxi + 274; 1940.

The relations between the United States and Canada have been characterized in the past by manifestations that are unique in the annals of international sociality. Among these manifestations, and probably the most important, has been the free interchange of populations. In this book, which constitutes the historical section of a demographic survey of the subject, the extent and direction of the more important phases of the population movement between Canada and the United States are described thoroughly and authoritatively. When the colonies were being founded, the westward movement of the people was the same above and below the border. With the revolution began a migration, fostered by the loyalists, from the United States to Canada. After the revolution had subsided the westward expansion in this country at first paralleled that of Canada but later assumed a speedier pace of its own. Coincident with the speeding up of this westward movement there was also a resumption of migration from Canada, as the economic opportunities in the United States became more advantageous. The Canadian migration, in general, exceeded that from the United States to Canada, and, except for some interruptions during the Civil War and World War I, continued until the depression of 1929 and the years that followed. In recent years signs of economic nationalism have developed and the migratory process from either side has virtually stopped. It may be that this situation is only temporary, or, on the other hand, it may manifest the maturity of the two countries. Neither Hansen nor Brebner has attempted to predict the future but in this admirable record of the past they have furnished the necessary groundwork for an understanding of what may occur.

DOCTOR IN ARABIA.

*By Paul W. Harrison. John Day Co., New York.* $3.00. 8½ x 5¾; [10] + 303 + 9 plates; 1940.

Twenty-nine years ago, after graduating from the Johns Hopkins Medical School and interning in a Boston hospital, the author decided to practise medicine in Arabia. This book is the story of his work in Oman, "a tiny opera bouffe empire in the southeastern corner of the Arabian peninsula, an empire of bare rocks, three hundred miles long and a hundred wide." Most of the author's work during his stay of nearly three decades in Arabia was in and about Muttreh, the suburb of Muscat, the latter being the capital of Oman and one of the three hottest places where white men live. Harrison writes most entertainingly of his numerous patients and their way of life—the city merchants, the date gardeners of the Bottina, the oasis Arabs, the Bedouins, the fishermen and Baloochees. He has a keen insight into the problems of the Arabian people. State medicine, he believes, is the only solution to the problem of bringing scientific medicine to the ordinary man in Arabia. "The date gardeners must be freed from malaria, the wandering nomads from Madura foot, the town dwellers from trachoma, syphilis, and gonorrhea. The lepers must be segregated and that dreadful disease eliminated." This narrative has been written with humour and understanding and should appeal to the inveterate travel-book reader. The numerous clinical cases cited and the discussion of the psychology of the Arabian patient should be of especial interest to the physician. There are excellent full-page photographs and one map of Oman and its surrounding territory.

JUNGLE IN THE CLOUDS.

*By Victor W. v. Hagen. Duell, Sloan and Pearce, New York.* $3.00. 8½ x 5⅜; x + 260; 1940.

The author, a naturalist, and his wife, Christine, a botanist, journeyed into the high cloud forests of interior Honduras to secure alive, photograph, and study the habits of the Quetzal, sacred bird deified for centuries by the Mayas and Aztecs. In this book von Hagen entertainingly describes their journey to the Sierra de Sulaco mountains, their sojourn in mountainous inland Honduras, and their successful quest for the King of the Trogons, the Quetzal,

> the most beautiful bird in the world. Not much larger than a pigeon, clothed in iridescent plumes quivering from gold to copper to deep jade, with a breast as red as blood hemorrhaging from a deep wound, this bird had given its name to the sweet-tempered god of the Aztecs and its three-foot plumes to the knights of the Plumed Serpent.

The author sent live Quetzals to the Bronx Zoo in New York City and the Zoological Garden in Regent's Park, London, and thereby broke a four-hundred-year-old legend that this bird could not live in captivity.

After the Quetzal hunt the author and his wife journeyed to Montana de la Flor and set up camp on the Rio Guarabuqui to study the ethnology of an "extinct" tribe of Jicaques, compile a vocabulary of Jicaquean words, and explore and photograph the aborigines' stockaded village. A more detailed report on this tribe is to be found in the author's *The Ethnology of the Jicaque Indians*. Following this adventure the author and his wife left for Copan, southernmost city of the ancient Mayan empire and one of the oldest of Mayan cities, to study and photograph the Copan ruins. There are end-paper maps and many excellent photographs.

HUMAN NATURE AND THE SOCIAL ORDER.

*By E. L. Thorndike. The Macmillan Company, New York.* $4.00. 8⅜ x 5⅜; xx + 1019; 1940.

The study of man's social behavior has in general been in the hands of philosophers of the arm-chair variety who have often confused faith with fact. Many biologists who have dealt with the subject have done no better and, of course, neither have many sociologists and psychologists. However, the recent tendency to evaluate quantitatively the action

of groups, to inquire into and measure social behavior characteristics provides a more hopeful outlook for the development of a social biology based on actual observations of overt human activities. Some observations of this kind are summarized and interpreted in this comprehensive treatise. In the first part Thorndike undertakes to delineate and to give a quantitative description of human variation with reference to the more important elements of social behavior including abilities and propensities, wants and their satisfaction. In the second part of the book an attempt is made to relate these characteristics of social variability to group manifestations and institutions (laws and civil regulations, forms of government, public health and welfare, etc.). In this part it is to be noted that the author unfortunately foregoes in places the empirical attitude. Notwithstanding some deviations towards the metaphysical the book on the whole lacks philosophical depth. Even so, and in spite of the inclusion of questionable material, this work represents a great step forward toward a more precise understanding of the social aspects of human biology.

MATTHIAS GISH OF WHITE OAK. *The History of an American Family.*

*By J. I. Hamaker. Obtainable from the Author, Randolph-Macon Woman's College, Lynchburg, Virginia.* $3.00. $7\frac{7}{8}$ x $5\frac{1}{4}$; 368; 1940.

White Oak is the name of the community (later changed to Liberty and now known as Penryn) in Lancaster County, Pennsylvania, where Matthias Gish settled with his family *circa* 1742. He is the founder of the Gisch (or Gish) clan (Dorothy and Lillian are probably the most widely known members) in this country. Primarily a history of this family in Penn's colony, and of the early vicissitudes and wanderings of its members away from the original community into Virginia, Kansas, and to the West Coast, the book is prefaced with a short account of the sectarians (the Brethren, the Mennonites, Dunkards, and Schwenkfelders) in Europe and the United States, and the diary of a journey from Bertelshof, Saxony, to Rotterdam and thence to America made in 1733 by a member of a group of Schwenkfelder refugees. The reader also gets side-lights into the early history of Penn's colony, the family life, education, housekeeping, and food of the early settlers and other matters peculiar to the sectarians in Pennsylvania and the other places where the Gish descendants settled. The book concludes with genealogical material, a bibliography and a copy of the Penn Patent.

A PIONEER DOCTOR IN OLD JAPAN. *The Story of John C. Berry, M.D.*

*By Katherine Fiske Berry. Fleming H. Revell Co., New York, London and Edinburgh.* $2.50. $8\frac{1}{2}$ x 6; 247 + 16 plates; 1940.

This biography of a medical missionary to Japan from 1872 to 1894 was written by his daughter. She describes the New England boyhood of her father, his medical training, and his journey with his young wife to the Land of the Mikados at the age of twenty-five. He entered the land at the beginning of the reign of Meiji, the Era of Enlightenment, only a comparatively brief period after the closed Empire had been opened to the world in 1859. The death knell had been sounded for feudalism, and exponents of Western civilization were invited into the land to teach the modern way of life. However, the feudal system did not perish without a struggle and it was a country adverse to the Western World that faced John Berry and his wife. He remained through this period of readjustment, fighting hostility and ignorance. He established the first hospitals and the first nurses' training school, taught the Japanese the science of sanitation, and introduced prison reform and social service work. Marquis T. Okubo compiled a brief biography of him, the first such book to have been written of an American by a Japanese. In addition to the full-page photographs there are many delightful small text illustrations which are redrawings from the works of Hokusa and other artists. A chronological summary of Dr. Berry's life

after 1894 and letters are included in the appendix.

A Surgeon's Life, *The Autobiography of J. M. T. Finney.*

*By J. M. T. Finney. G. P. Putnam's Sons, New York.* $3.50. 9 x 6; xiv + 396; 1940.

Doctor Finney (b. 1863, in Natchez, Mississippi) received his medical degree from Harvard in 1884 and immediately was assigned to the Resident Surgical Staff of the Massachusetts General Hospital. At this time aseptic surgery was in the embryonic stage, and the controversy on the respective merits of antiseptic and aseptic methods raged between members of the staff. In 1889 he was called to the newly opened Johns Hopkins Hospital where the planning and construction of the surgical building, operating rooms and accessories had to wait until the question of surgical technique became more stabilized. As Finney has been associated with this hospital ever since, the story of his career parallels the growth of the surgical units from their beginning. His contributions to their development are told with modesty. In addition, Finney tells of his childhood and youth, private practice, his experiences as Chief Consultant in Surgery to the A.E.F., his vacations and recreations, his friends (among them some of our greatest surgeons—the 17 pages devoted to Halsted are fine), and other matters of human interest. His is an interesting story, told with genial humor but freed from the rather blatant calculations at exhibitionism so often found in autobiographies of medical men.

Foundations of American Population Policy.

*By Frank Lorimer, Ellen Winston and Louise K. Kiser. Harper and Bros., New York and London.* $2.50. 8½ x 5¾; xiii + 178; 1940.

With the possible exceptions of the immigration restrictions and of the few localized attempts to direct migration from one area of the country to another, the United States has yet to demonstrate any official concern for problems of population. However, if the present political trend continues it is to be expected that eventually some public policy will be formulated. In seeming anticipation the authors briefly and superficially examine the demographic conditions of the country (population, natural resources, health, production, consumption, etc.) and arrive at an outline of the kind of population policy that to them seems desirable. The measures which they advocate are indefinitely stated but in the main involve (a) economic readjustment for certain portions of the population, (b) increased public health and welfare work, (c) spread of knowledge of, and further research on, contraceptive techniques. On the whole, the vague tone and the multiplicity of the propositions advanced seem to indicate that they are not maturely considered or critical views, derived either from an adequate survey of demography or from the history of population policies in other countries and other periods.

The Seven Chars of Chelsea.

*By Celia Fremlin. Methuen and Company, Ltd., London.* 5s. net. 7¼ x 5⅛; vii + [5] + 178; 1940.

After graduation from Oxford University the author became successively a kitchenhand, scullery-maid, charwoman in a hospital, maid-of-all-work, milk-bar assistant, and cook-general. The first half of this book gives a lively account of her experiences—not all of the humor and criticism being at the expense of the servant class. In the latter half, deductions are drawn with reference to psychological and sociological aspects, especially on problems of class distinctions in England. The antagonism between classes, the author claims, is artificially produced, and she suggests the historical economic background of the psychological barriers. Little enthusiasm is shown for the Domestic Workers' Union, but it is considered necessary as a means of attacking the symptoms of the present social system.

It offers an inhuman and efficient system instead of an inhuman and inefficient one. . . . The goal before the Union is a state of society in which it will no longer have any place; a state of society in which maid and mistress are of the same class, with the same cultural background and the same education.

WAGES, HOURS, AND PRODUCTIVITY OF INDUSTRIAL LABOR 1909 TO 1939. *U. S. Department of Labor. Serial No. R. 1150. By Witt Bowden. Government Printing Office, Washington.* 9⅛ x 5⅞; 28; 1940 (paper).

The original purpose of this study was concerned with wages. The nature of the data collected, however, permitted analyses of related problems, namely: labor productivity and purchasing power, weekly hours, weekly earnings, employment, total wages, and wage earners' share of income paid out.

The years covered by the study were from 1909 to 1939. The industries treated were manufacturing, mining, and railroad transportation. During this period the average hourly earnings rose from 20.7 cents in 1909 to 66.1 cents in 1939. Even with the cost of living taken into consideration the wages of 1939 were 101.5 per cent higher than those of 1909. Average hours of work fell from 51.7 per week in 1909 to 37.8 in 1939. In spite of this, there was a gain in real weekly earnings of 47.0 percent. The details of this and the additional studies reported are given in 8 tables and 6 charts.

THE SU SITE EXCAVATIONS AT A MOGOLLON VILLAGE, WESTERN NEW MEXICO 1939. *Anthropological Series. Field Museum of Natural History. Vol. 32, No. 1. Publication 476. By Paul S. Martin, John Rinaldo and Marjorie Kelly. Field Museum of Natural History, Chicago.* $1.50. 9¼ x 6⅜; 97 + 11 maps; 1940 (paper).

This publication comprises the findings of the Field Museum Archaeological Expedition to New Mexico (summer, 1939) in an early-type Mogollon village in the Apache National Forest in western central New Mexico. The village was named the SU site because of its nearness to the SU canyon and ranch. There is a brief discussion on the Mogollon problem and the existence of the little-known Mogollon culture as a separate third complex of the ancient Southwest. Following this are the descriptions and photographs of seven pit houses, one surface house, the artifacts, pottery, and burials found on the site. In addition there are diagrams of ground plans and sections of the houses, a postulated method of pit-house construction, and a drawing showing the excavated area. The many photographs and well-drawn maps and diagrams serve to make the report an elucidating one for the student of the ancient culture of the Southwest.

TEST TUBES AND DRAGON SCALES. *By George C. Basil in collaboration with Elizabeth F. Lewis. John C. Winston Co., Chicago, Philadelphia and Toronto.* $2.50. 8¾ x 6¼; xi + 316; 1940.

Any wide-awake doctor in a foreign land could turn out human-interest stories by the volume, but not many of them could resist, as Basil has, the temptation to assume a superior attitude. The picture of Chungking and the surrounding Chinese hinterland before they became the center of resistence of a resolute people is fascinating. The difference between native ways and those represented by the American hospital marks the meeting of divergent traditions; yet people are much alike everywhere. The suspicious Chinese colonel fundamentally is little different from the indignant U. S. naval commander in similar situations; and the poorest Negroes live just as precariously in Annapolis alleys as do the Chinese squatters outside Chungking's walls. The author's account of his trips into the west and southwest, far from any connection with the occident, are full of color. So are his other stories of places. But one leaves the book with the impression that Basil's chief interest is in China's people.

WHO WALK ALONE.

*By Perry Burgess. Henry Holt and Company, New York.* $2.75. 8 x 5⅛; viii + 308 + [4]; 1940.

The central figure—this, incidentally, is not the author, in spite of the fact that the story is written in the first person—is an American soldier who spent some time in the Philippines during the insurrection. Nine years after his return to the United States signs of leprosy appeared. After being treated in New York for a year and showing no improvement, the patient was sent to the leper colony on the Island of Culion in the southern Pacific, where he remained a member of the colony, a hopeless case, for upwards of a quarter of a century. The book gives a picture of the life led by members of the Cape Colony, the fine medical work of the officers and nurses (less than one percent ever contract leprosy), and the various methods used in the treatment of the disease, especially the use of chaulmoogra oil.

Included in the volume are a number of illustrations, an appendix, in which are given questions commonly asked about leprosy and their answers, and an index.

FAMILY INCOME AND EXPENDITURES. *Southeast Region. Part 1, Family Income. U. S. Department of Agriculture. Miscellaneous Publication No. 375. Consumer Purchases Study. Urban and Village Series.*

*By Dorothy Brady, Day Monroe, Gertrude S. Weiss and Thelma Dreis. Government Printing Office, Washington.* 35 cents. 9¼ x 5¾; v + 389; 1940 (paper).

This study, part of a comprehensive survey to provide data on the way in which American families earn and spend their incomes, covers small-city and village families in the Southeast region of the United States. In order to reduce the number of variables, only families in which the husband and wife were both native-born were studied. White and Negro families were included, but families in unusual situations were excluded. Section 2 deals with village families; Section 3 with small-city families. Fully half the volume is taken up with appendices which contain much tabular matter. Altogether there are 191 tables in the report.

LEIF ERIKSON THE LUCKY.

*By F. A. Kummer. John C. Winston Company, New York.* $2.00. 9 x 6; 245; 1940.

Although these pages were written primarily for young people, they will delight all readers who appreciate the spirit of adventure. In its personal details the book is fiction, but it is based on historical facts and Norse modes of living of that era. Thus it tells of the government, laws, Yuletide festivities, methods of warfare, shipbuilding, and household activities. Of prime importance in directing Viking exploration was the tide of Christianity, forcing unconvertibles ever westward to Iceland, Greenland, and finally to more distant western shores. Only a small portion of the book deals with these later journeys to our Atlantic coast, as it tells mainly of the adventures of Leif's youth. The customs and courage of the people and their ceaseless struggle against the sea are admirably illustrated in pen and ink.

FAMILY BEHAVIOR. *A Study of Human Relations. Second Edition, Revised.*

*By Bess V. Cunningham. W. B. Saunders Co., Philadelphia and London.* $3.00. 7¾ x 5½; 527; 1940.

In this second edition (the first edition was reviewed in Q.R.B., Vol. 11, p. 466) the author has augmented the factual bases of her discussion by including new data on changes in family size, economic factors in marriage and family income, and on elements of divorce. The distinctive feature of this work is the excellence of the survey of the literature on the psychological and sociological aspects of inter- and intra-familial relations and the interpretation which the author gives to the reports cited. The biological aspects of the family, however, are not adequately considered. Aside from this shortcoming, which is common to most studies on the

family, this book can be highly recommended as a source of reference for college students.

DERSU THE TRAPPER.

*By V. K. Arseniev. Translated from the Russian by Malcolm Burr. E. P. Dutton and Co., New York.* $3.00. 8½ x 5¾; vii + 352; 1941.

An entertaining story of travel experiences in the Soviet Far East by the Russian geographer, ethnographer, and geologist, Arseniev. A valued member of the explorer's party was Dersu Uzala, "a primitive hunter who had spent his entire life in the tiagá [forest] and was exempt from all the vices which our urban civilization brings in its train." It was Dersu's resourcefulness and courage that frequently saved the party from disaster in the vast forest of Northern Asia. His wide knowledge of the ways of nature, many glimpses of which the author gives us, immeasurably added to the accomplishments of the three survey parties which Arseniev led, preliminary to the opening up of this vast uninhabited region for settlement and industrialization.

THE CHORTI INDIANS OF GUATEMALA.

*By Charles Wisdom. University of Chicago Press, Chicago.* $4.50. 8 x 5¼; xiv + 490; 1940.

In this report the author presents a complete picture of the cultural and social organization of the Chorti-speaking Indians, an agricultural people, whose present habitat is in east-central Guatemala, extending at the eastern boundary about ten miles into Honduras to the *municipio* of Copan.

The Chorti area was the locale of the Old Empire Maya civilization of which Copan was the culture center. Excepting the Ladinos, it is now occupied only by Chorti, who may well be direct descendants of the pre-Conquest Copan people and whose language may be fundamentally the same as that spoken at ancient Copan.

There are excellent photographs and drawings. A glossary and an index are included.

OUR SHIFTING POPULATIONS.

*By Mark A. Dawber. Joint Committee on Publicity and Promotion of the Home Missions Council and Council of Women for Home Missions, 297 Fourth Ave., New York.* 25 cents. 9 x 6; 68; 1940 (paper).

The radio talks in this series, under the general head of *Frontiers of American Life*, were planned to accord with the program of discussion in the 1940–41 meetings of the home mission study groups in the United States. The factual material was gleaned from various sources with which the sociologist is already familiar. The advice to church groups as to what they can do to aid the community solve the problems raised by the presence of migrants, and aiding the individuals of the various migrant groups (sharecroppers, migratory urban workers, "river folk", the migrant Negro, refugees, etc.), smells less high of "uplift" and "religion" than might be expected.

I BOUGHT A MOUNTAIN.

*By Thomas Firbank. Countryman Press, Guilford, Vermont.* $2.75. 8½ x 5¾; 320; 1940.

This is the story of a young Canadian who, after two years of uninteresting work in a canning factory in Canada, unexpectedly bought a mountain farm when travelling in Wales. It is interestingly written and the general reader will find it entertaining. It is more particularly of interest to the agriculturist in that the main business of farming had to do with sheep raising, of which the fledgling farmer had little knowledge. Firbank's Welsh neighbors, wise by heritage in the care and breeding of sheep, came to his aid. Much of their sage advice concerning the breeding and rearing of sheep is herein reported; also many of the author's failures in this and other lines of farming.

PLOWING THROUGH. *The Story of the Negro in Agriculture.*

*By Edwin W. Hullinger. William Morrow and Co., New York.* $1.50. 10½ x 7¾; 60; 1940.

Textual matter and numerous illustrations of a propaganda hue, explain how the National Farm Program is seeking to improve the health, the education, and the economic condition of the Southern Negro.

THE FIFTH COLUMN IN WASHINGTON. *Un-Americans on the Government Payroll. By Joseph P. Kamp. Constitutional Education League, New Haven, Conn.* 25 cents. 9 x 6; 33; 1940 (paper).

## ZOÖLOGY

THE MAMMALS OF CHINA AND MONGOLIA. *Natural History of Central Asia, Vol. XI, Part 2.*

*By Glover M. Allen. Central Asiatic Expeditions, American Museum of Natural History, New York.* $10.00. 11 x 8½; xxvi + 730 + 11 plates; 1940.

This fine survey of the natural history of China and Mongolia is destined to become one of the classics in biological literature. During the years 1921–1930 the Central Asiatic Expeditions secured large collections of biological specimens and many photographs. The reports in the different fields are being issued from time to time. When completed they will comprise a series of 12 quarto volumes.

The present volume, the second part of Volume XI (cf. Q.R.B., Vol. 14, p. 85 for mention of the first part) is devoted largely to the typical rodents—the squirrel-like mammals, mouse-like and rat-like rodents, Jerboa-like rodents, and porcupines and their allies. Then follows a much smaller section on the even-toed and odd-toed ungulates, and one on the sea cows. In Volume XI something over 500 mammalian forms are described. The treatise is greatly enriched by the numerous measurements on many forms, aside from the type specimens, which were made by collectors on fresh specimens in the field. The seventeen preliminary papers by Allen on the material have been embodied in the volume. In Part 1 is given an extensive mammalian bibliography, while Part 2 concludes with a complete index of 57 pages.

In preparing the distribution maps which appear as text figures Allen has taken into account the political changes that have brought about new boundary lines for certain provinces. This must have added appreciably to his labors. In spite of the comprehensive character of the report, Allen states that there are still large areas, particularly in the southern portions of China, yet to be surveyed.

A TEXT-BOOK OF ZOOLOGY. *Vol. I. and Vol. II. Sixth Edition.*

*By the late T. Jeffery Parker and the late William A. Haswell. Vol. I revised by Otto Lowenstein; Vol. II revised by C. Forster-Cooper. The Macmillan Co., New York and London.* $9.00 each. 9¼ x 6½; Vol. I: xxxii + 770; Vol. II: xxiii + 758; 1940.

This fine text requires no introduction to biologists. For forty odd years it has been one of the outstanding guides for the beginner. To those who have been nourished on it and who have proceeded into the higher realms of zoology, "Parker and Haswell" will always remain a necessary part of their reference library.

The two volumes first appeared in 1898. Since that time revision has kept pace with changing ideas that the years have wrought. The present edition has been thoroughly revised without in any way departing from the original inductive treatment of the subject matter. Otto Loewenstein, Lecturer in Zoology at the University of Glasgow has revised the first volume; C. Foster-Cooper, now Director of the Natural History Section of the British Museum, the second. Some of the major changes are as follows: the chapter on "General structure and physiology of animals" has been largely rewritten, with new illustrations; all chapters dealing with classification have been thoroughly revised and examples included

to enable the student to ascertain the systematic position of the animals mentioned in the comparative chapter on "General organization"; a new classification of the Fishes is given in which four classes are recognized; the section on Mammals has been enlarged and some extinct forms included. Due to lack of space the sections on Geographical distribution, the Philosophy of zoology, and History of zoology which formed part of the earlier editions have been withdrawn.

INTRODUCTION TO PARASITOLOGY, *With Special Reference to the Parasites of Man. Sixth Edition, Rewritten and Enlarged.*

*By Asa C. Chandler. John Wiley and Sons, New York; Chapman and Hall, London.* $5.00. 9 x 6; xiii + 698; 1940.

New advances in the study of parasites have necessitated a revision of Chandler's textbook of parasitology (cf. Q.R.B. Vol. 11, p. 354 for mention of fifth edition). As the title indicates, the sixth edition deals chiefly with the parasites of man, with brief considerations of the more interesting and important species found in lower animals. Discussions of parasites and the diseases they cause include sections on morphology, distribution, biology, pathogenicity, epidemiology, diagnosis or identification, treatment, prevention, and control. With the exception of the two introductory chapters, which deal with history and general biology of parasites, the book is divided into three parts: Protozoa, Helminths, and Arthropods. Classifications of the larger groups, and keys to some of the genera and important species, are printed in small type. Fortunately, the author has included those organisms with uncertain systematic positions: the viruses, Rickettsias, *Bartonella*, and the spirochaetes. A short bibliography is given at the end of each chapter.

Written primarily for college students, the book is an excellent, up-to-date summary of the field, and should be invaluable not only to beginners, but also to teachers, who will find it a useful reference book and guide in their courses.

BIRDS OF THE GREY WIND.

*By Edward A. Armstrong. Oxford University Press, London and New York.* $3.50. 8½ x 5½; xv + 228; 1940.

A combination of bird student and poet wrote this interesting collection of stories on the birds of northern Ireland—bird student because the author reveals a wide and constant association with birds that has enabled him to learn many of their habits and mannerisms; poet because these observations are beautifully described in delightful essays which are interspersed throughout with references from the Irish poets, and from the legend and folklore of County Antrim. The love of the author for his country and its birds is manifest all through the book by his nostalgic portraiture of field, mountain, and lough.

The merganser, the swan, the oystercatcher, the cuckoo, the short-eared owl, are but some of the birds with which the author has become well acquainted and of which he writes more fully. There is much good ornithological material to be garnered from these pages; the author believes that birds are more plastic in their behavior than is commonly held, and in order to interpret their actions and reactions in a better manner, the observer should watch with something more than cold scientific objectiveness.

The bird photographs, some taken by the author and others by his friends, are excellent and deserve special commendation.

THE CHILDHOOD OF ANIMALS.

*By Sir P. Chalmers Mitchell. Penguin Books, Harmondsworth and New York.* 25 cents. 7 x 4¼; 243; 1940 (paper).

The author, besides being Secretary of the Zoological Society of London for more than 30 years, was also the creator of Whipsnade Zoological Park. This zoo emphasizes the natural environments of animals instead of the usual cages of stone and iron bars. For this reason he has had excellent opportunity to study animal life under more or less natural conditions and, as a trained professional zoologist, has

observed and recorded the habitats of many wild animals whose life histories are little known.

The book is limited to the childhood of animals, gleaned not only from observations in the park, but also from the literature and experiences of others. The duration of youth, the color patterns of the young, the limitation of families, brood-care, food and taming of the young, are but some of the subjects ably recounted. Emphasis is on birds and mammals although other vertebrates and many invertebrates are included to round out the discussions. In many places the author inserts his own ideas and interpretations, all of which are well made and in many cases, most stimulating. A thoroughly delightful book, well written and authentic.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXV, Part 3, Numbers 19–24.*

*New York Zoological Society, Zoological Park, New York.* $1.10. 10½ x 7; 87 + 4 plates; 1940 (paper).

The following papers are contained in this number: Eastern Pacific Expeditions of the New York Zoological Society. XX. Medusae of the Templeton Crocker and Eastern Pacific *Zaca* Expeditions, 1936–1938, by Henry B. Bigelow (20 text-figures); Two new species of Trematodes (*Apharyngostrigea bilobata:* Strigeidae, and *Cathaemasia nycticoracis:* Echinostomidae) from herons, with a note on the occurrence of *Clinostomum companulatum* (Rud.), by O. Wilford Olsen (1 plate); Nesting of the sunfish, *Lepomis auritus* (Linnaeus), in tidal waters, by Neil D. Richmond (1 plate); Eastern Pacific Expeditions of the New York Zoological Society. XXI. Notes on Echinoderms from the west coast of Central America, by Hubert L. Clark (2 plates, 4 text-figures); The nesting behavior of *Eupomotis gibbosus* (Linnaeus) in a small pool, by C. M. Breder, Jr. (2 plates, 2 text-figures); Reproductive activities of a hybrid minnow, *Notropis cornutus* × *Notropis rubellus*, by Edward C. Raney.

MOSQUITO CONTROL. *Practical Methods for Abatement of Disease Vectors and Pests. By William B. Herms and Harold F. Gray. The Commonwealth Fund, New York; Oxford University Press, London.* $3.50. 10 x 6¾; xii + 317 + 23 plates; 1940.

This book has been written with the needs of engineers, physicians, and entomologists in mind.

It is intended to be a practical handbook on mosquito abatement, not a textbook on drainage engineering or a technical monograph on entomology. It endeavors to present the fundamental principles of mosquito control, emphasizing practical application, geographic variation, and ecological differences in sufficient detail to indicate the main methods of attack on the problem. . . . References to the literature are intended to be representative rather than exhaustive.

A wide range of topics is included: education of the public, state laws, breeding places of mosquitoes, drainage and reclamation, oils, larvicides, and the economic aspects of this phase of public health work. The usefulness of such a book is obvious; it should find ready welcome by those engaged in such activities.

WINGS AT MY WINDOW.

*By Ada C. Govan. Illustrated by Dorothy Bayley. The Macmillan Co., New York.* $2.50. 8 x 5½; xiv + 198; 1940.

A chickadee landed on the window sill near a bed-ridden mother and thereby started a remarkable tale. Inspired by this visitor, the patient started to feed the bird and then there shortly evolved a huge program of bird feeding and observing that culminated first in the patient's recovery both in body and soul, and second, into a bird banding station that produced some interesting ornithological records.

Recorded herein are the courtship antics of numerous birds, especially that of the purple finch. Some banding records of rose-breasted grosbeaks, other acute observations on bird behavior all add to make this book interesting and in some respects valuable. The professional ornithologist may be displeased with the subjectiveness of the author's observations and interpretations, but then the book was not written to replace a text.

ESSENTIALS OF ZOOLOGY, *Emphasizing Principles of Animal Biology.*

*By George E. Potter. C. V. Mosby Co., St. Louis, Mo.* $3.75. 8½ x 5½; 526; 1940.

With the help of several biologists, Potter has organized an excellent text for use in a college course of general zoology. Aiming at a well-rounded course, he has stressed not only the essentials of taxonomy, anatomy and physiology of a representative member of each phylum of animals, but has included pertinent discussions on animal genetics, animal anomalies, animal ecology, and evolution.

The logical organization of the textual material, the abundance of well-chosen illustrations, the detailed table of contents, the glossary, and the complete index, as well as the new eye-tone paper on which the text has been printed, are all factors which point to the high quality of this volume.

PLANT GALLS AND GALL MAKERS.

*By E. P. Felt. Comstock Publishing Company, Ithaca.* $4.00. 9 x 5¾; viii + 364; 1940.

The author's *Key to American Insect Galls* which was published as the New York State Museum Bulletin Number 200 in 1917, and of which the supply has long since been exhausted, here appears in a rewritten and extended version. The section on gall wasps on oaks, especially, has been extended to include the important contributions and a long series of photographs made by A. C. Kinsey and L. H. Weld.

Part I (35 pages), serving as introduction, discusses gall types, the principal gall-producing insects and their biology, alternation of generations, economic importance, the various ways in which galls are developed, and methods of collecting them. Part II gives a list and classification of the galls, arranged according to plant host. This part is generously illustrated with photographs and drawings.

Technical terms have been avoided as much as possible in order to bring this exhaustive work within the appeal of the interested general reader, but its value to the specialist is not thereby reduced. A short bibliography and an index are appended.

THE CONTROL OF ORGANISMS.

*By Frederick L. Fitzpatrick. Bureau of Publications, Teachers College, Columbia University, New York.* $2.75. 8½ x 5½; xi + 334; 1940.

The organisms referred to in this title are those commonly designated "pests." Some of them convey diseases, some cause diseases, both in man and his domesticated beasts of burden, others attack his crops, while still others invade his home and wreak devastation among his books, furniture, and clothing.

The natural history of all such economically significant organisms is set out in detail, with instructions for combating them, and in addition the history of man's effort to combat disease from the days of Hippocrates to those of Ehrlich. Without this the book would be dry reading indeed.

The index covers twelve pages, but the bibliography is painfully short, and even the author's apology does not compensate for its brevity.

INTRODUCING INSECTS. *A Book for Beginners.*

*By James G. Needham. Illustrations by Ellen Edmonson. Jaques Cattell Press, Lancaster, Penna.* $1.50. 7½ x 5½; v + 129; 1940.

The purpose of this little volume is to acquaint the general public with insects, both good and bad. The textual material includes discussions of the identifying characteristics, the life histories, and the economic importance, as well as the best methods of control of a number of our common insect pests. For anyone whose interest in insects extends beyond that of simply wanting to read about them, there are several chapters dealing with the materials and techniques of collecting and rearing them. The book is written very

simply, in non-technical language. It is well supplied with illustrative material and carries both a brief table of contents and an index.

FISH PRODUCTION.

*By Josephine Perry. Longmans, Green and Co., New York and Toronto.* $1.50. 8 x 5⅜; 104; 1940.

The many techniques and materials used in fishing have made for great specialization. Thus the fisherman versed in the use of a net is seldom competent at line fishing; the trawl fisherman will seldom be proficient at shore fishing. This book gives, in simple language, the details of the methods used in the various divisions of the fishing industry. A short chapter on fish hatcheries and fish conservation is also included. The book was written, as stated by the author, "to interest young grade-school students in an important national industry of which little is known". The volume well fulfills this aim. It is profusely illustrated and an index is appended.

AMERICAN SONGBIRDS.

*By Maitland A. Edey. Random House, New York.* $1.00. 11 x 8½; 72; 1940.

The most attractive feature of this book is its low price, a fact that will enable any young bird student to own a well-illustrated guide to our native (eastern North America) songbirds. The color plates are those of Fuertes that first appeared in the *Birds of New York*. It is too bad that the illustrations could not have been printed a little more carefully, aside from the fact that they show wear. The text material is limited to a few descriptive notes on the 108 species herein considered and a brief introduction to bird study.

POMATOCEROS, SABELLA AND AMPHITRITE. *L. M. B. C. Memoirs on Typical British Marine Plants and Animals, XXXIII. Edited by R. J. Daniel. Department of Oceanography, University of Liverpool.*

*By Joan G. Thomas. University Press of Liverpool, Liverpool.* 12s. 6d. net. 9½ x 6; vii + 88 + 11 plates; 1940.

This memoir consists of an anatomical report on three species of sedentary polychaetous worms, *Pomatoceros triqueter, Sabella pavonina*, and *Amphitrite johnstoni*. It is pointed out how the peculiarities of these three worms are correlated with their specialized mode of life. Numerous plates illustrate the somewhat technical text material which includes the major anatomical systems and brief notes on development.

HONEYCRAFT *in Theory and Practice.*

*By J. A. Lawson. Diagrams by Audrey Lawson. Chapman and Hall, London.* 3s. 6d. net. 7¼ x 4¾; xii + 228; 1940.

This is a "cheaper edition" of a well-known British book on bee-keeping which was first published in 1931. It is "a severely practical book", as the author meant it to be. It is abundantly illustrated, and nothing pertinent to the subject seems to have been omitted. Yet the book is succinctly and exceptionally well written. The author is a Fellow of the Royal Entomological Society.

CHILDREN OF THE SEA.

*By Wilfrid S. Bronson. Harcourt, Brace and Co., New York.* $2.00. 8¾ x 6⅝; [8] + 264; 1940.

This is a book for children. It is the story of a porpoise and the pickaninny that made friends with it. The illustrations are artistically executed.

While the book has no special scientific value, it is scientifically accurate. It has more in common with "Peter Rabbit" than with "Uncle Wiggly Longears." It is imaginative fiction of the better type.

INDEX-CATALOGUE OF MEDICAL AND VETERINARY ZOOLOGY. *Part 4. Authors: D to DŽUNKOVSKI. U. S. Department of Agriculture.*

*By Albert Hassall, Mildred A. Doss, Ruth M. Taylor, Gertrude B. Carson and Dorothy Bero. Government Printing Office, Washington.* 30 cents. 9⅛ x 5¾; 961–1176; 1940 (paper).

Mention has already been made in these columns of the earlier parts of this revised index-catalogue [cf. Vol. 13, p. 468 (Parts 1 and 2) and Vol. 15, p. 96 (Part 3)]. As in the earlier numbers the index section is preceded by a list of abbreviations for libraries and for serial publications. We again call attention to the biologist of the usefulness of this index.

## BOTANY

ILLUSTRATED FLORA OF THE PACIFIC STATES, *Washington, Oregon, and California. Vol. I. Ophioglossaceae to Aristolochiaceae. Ferns to Birthworts.*

*By Leroy Abrams. Stanford University Press, Stanford University; Oxford University Press, London.* $7.50. 10½ x 7; ix + 538; 1940.

This monumental work is to appear in four volumes. Volume I, dealing with ferns to birthworts (1299 species), was first issued in 1923 but the paper upon which it was printed was unsatisfactory. A reprinting, with some revision, has now been made on a paper of lasting qualities. The publishers announce that copies of the 1923 printing will be accepted for $3.00 credit toward the purchase of a new copy.

The three Pacific states, roughly 1,300 miles in length and 250 miles in width, traversed by two great mountain systems, and possessing a widely divergent rainfall, furnish conditions for an extensive flora of great complexity. There are sound reasons for the belief that in temperature the climate of the coastal region of the present time has changed but little from what it was in the Cretaceous Period, the Pacific ocean having served throughout the ages as a great thermostat. Thus the climatic conditions and the physical barriers would account for the large numbers of endemic genera and species of plants. The presence of the boreal plants in the high mountain ranges, far from their normal habitat is probably due, in part at least, to the Glacial Period, while the flora of the Great Basin and Mexican elements have pushed in from the east and south.

The *Illustrated Flora* is designed to be a comprehensive reference work, describing and illustrating every species of fern, flower, tree, and shrub known to grow wild in the area. In designating distribution, Merriam's system of Life Zones has been used, since geographical distribution by states is quite inadequate. The table of contents is arranged first according to the scientific names of the families, followed by a second arrangement according to the English names. An index to generic and family names completes the volume.

While of special interest to the student of botany, everyone interested in the native plant life of the Pacific States will find this work a valuable handbook.

TEXTBOOK OF BOTANY.

*By E. N. Transeau, H. C. Sampson and L. H. Tiffany. Harper and Bros., New York and London.* $4.00. 9¼ x 6¼; xi + 812; 1940.

A traditional query (vocalization often repressed) of beginning students in a science is, "But what does all this stuff mean to *me*?" The authors answer this question by a departure from the standardized, not to say dull, method of plunging the student into a maze of classification and morphological characteristics. Instead, most of that "stuff" is brought out in ecological considerations which reveal just how vital the study of botany is to the welfare of man. Next in importance is the thorough treatment accorded plant physiology and the interrelationship between structure, function, and environment. The most recent advances of scientific research in both ecology and physiology are incorporated in the volume. In addition to descriptions of the various components of typical plants, the fungi, bacteria, mosses, ferns, and underwater plants are also discussed. A considerable

section is devoted to heredity and a chapter to plants of past ages.

The book will probably prove most useful as supplementary reading since its arrangement may not conform to most teachers' established order of presenting the material. Each chapter is concluded with a list of references. A thorough index is provided.

CHINESE HOUSES AND GARDENS.

*By Henry Inn. Edited by Shao Chang Lee. Fong Inn's Limited, Honolulu.* $5.00. 12 x 9; xii + 140; 1940.

Mr. Inn, a resident of Honolulu and a student and collector of Chinese art, spent a number of years traveling in China, photographing Chinese homes and gardens, and drawing designs of details which did not lend themselves well to photography. Urged by his friends to publish them in book form, he secured the collaboration of Mr. Lee and several other eminent authorities on Chinese life and art in writing the five articles of which the first part of the book is composed. The second part consists of photographs of parts of homes and gardens and detailed drawings by the author of window grills, panels, railings, benches, etc. As many of the homes and gardens portrayed have been damaged or completely destroyed by the war, we have in this beautiful book an important record of Chinese architecture and gardens. Landscape architects, gardeners, and interior decorators will find much of interest and of practical value in the photographs and drawings.

ELEMENTS OF BOTANICAL MICROTECHNIQUE.

*By John E. Sass. McGraw-Hill Book Co., New York and London.* $2.50. 9 x 6; ix + 222; 1940.

The need for a text which would include all the pertinent knowledge and essential techniques for collecting, preserving, staining, embedding and sectioning botanical material for microscopic study has been the underlying stimulus for the preparation of this volume. As an authority in both botany and microtechnique, Sass is well qualified for writing such a book. In addition to the general techniques employed in the preparation of various structures of the four phyla of plants for study under the microscope, the author has included several chapters dealing with the criteria for successful processing, the preparation of whole mounts, the construction, use and care of the microscope, and some worthwhile suggestions for successful photomicrography. The text is well illustrated and carefully indexed.

MANUALE DI PATHOLOGIE VEGETALE.

*By Raffaele Ciferri. Società Anonima Editrice Dante Alighieri, Genova, Roma and Napoli.* 50 Lire. 9 x 5¾; xxiii + 730; 1941 (paper).

This manual has been prepared to fill a long-felt need in Italian scientific literature for an adequate didactic treatment of plant pathology, and for use in Italian universities. It is marked by its clear and relatively brief critical discussions of various arguments raised in the more recent literature on the subject, and by numerous references to phytopathological contributions in Italy and elsewhere that have been advanced in the study of plant diseases. After a complete historical and analytic development of the subject from antiquity to the present the author progresses to more specialized phases: diseases and changes produced by non-parasitic causes; virus diseases; diseases caused by cryptogamic parasites; mixothallophytic diseases; fungous diseases; and the phanerogamic parasites. An appendix on checking grass infections is included. The work is profusely illustrated with drawings and photographs; it is well annotated, and indices to authors and subjects have been added.

SHRUBS IN THE GARDEN AND THEIR LEGENDS.

*By Vernon Quinn. Illustrated by Marie A. Lawson. Frederick A. Stokes Co., New York.* $2.50. 8 x 5¼; x + [2] + 308; 1940.

A companion book to Miss Quinn's *Stories and Legends of Garden Flowers*. In an interesting and informal manner she writes of thirty of the most popular garden shrubs, devoting a full chapter to each. She describes the most desirable species and varieties, tells their history and legends and folklore about them. Here and there between legends and folklore are valuable bits of information concerning the culture of the shrub and its uses in the planting scheme.

Amateur and professional gardeners alike will find this book worthy of their attention, and the general reader will find it interesting. The text is profusely illustrated and interpreted with drawings by Marie A. Lawson. There is an index of both botanical and common names of the shrubs and a table grouping them into orders and families.

THE HOME GARDENING ENCYCLOPAEDIA. *Edited by Walter Brett. Chemical Publishing Co., New York.* $2.50. 8¾ x 5½; 448 + 8 plates; 1940.

This encyclopaedia contains a wealth of practical information for the gardener both in England where the book was written, and in this country. However, much of the information will need to be adapted to the varying climatic conditions of our country. The month by month planting calendar is of doubtful value to gardeners here. Some of the suggestions for the control of pests are rather quaint. Even the most ardent gardener in the United States would hardly "dig up some worms, take them to a chemist, and ask him to impregnate them with poison", to be used as mole bait.

The volume has thirty reference charts, eleven illustrations showing practical gardening operations, and eight color plates of garden plants.

AMERICAN WILD FLOWERS. *By Cecile H. Matschat. Random House, New York.* 50 cents. 10½ x 8; [28]; 1940.

A picture book and not a detailed guide to American wild flowers. It is outstanding for its beautiful full or half-page color plates of eighteen wild flowers. Accompanying each plate is a short text. The inside covers contain small green and white drawings and short notes on twenty-four additional wild flowers. A list of the wild flowers illustrated and arranged according to their season of bloom is included. The book should be helpful to teachers of nature study, scoutmasters, camp counselors, and librarians of juvenile literature.

THE FERNS AND FERN ALLIES OF WISCONSIN. *By R. M. Tryon, Jr., N. C. Fassett, D. W. Dunlop and M. E. Diemer. Department of Botany, University of Wisconsin, Madison.* $1.00. 10 x 6⅝; v + 158; 1940.

A total of 118 species, varieties, forms, and hybrids of ferns and fern allies known to grow in Wisconsin are described. The ferns are represented by three families—the *Polypodiaceae*, *Osmundaceae* and *Ophioglossaceae;* and the fern allies by five—the *Salviniaceae*, *Equisetaceae*, *Lycopodiaceae*, *Selaginellaceae* and *Isoetaceae*. The descriptions, drawn from herbarium specimens, consist of short characterizations. The book is profusely illustrated with photographs, drawings, and maps showing the localities where the species or varieties have been found. A glossary and an index, giving both scientific and common names, have been provided.

STUDIES OF CENTRAL AMERICAN PLANTS—I. *Field Museum of Natural History, Botanical Series, Volume 22, Number 4.* *By Paul C. Standley and Julian A. Steyermark. Field Museum of Natural History, Chicago.* 75 cents. 9½ x 6; 103; 1940 (paper).

This report is devoted principally to descriptions of new species of Guatemalan plants, to notes regarding species new to the country, and to those of rare occurrence in Guatemala or in other parts of their range. The data given here represent

only a small part of those worthy of report, and additional matter will be published later.

UNIVERSITY OF COLORADO STUDIES. *Series D. Physical and Biological Sciences, Vol. I, No. 2.* Containing the Following Articles: *Magnetic Double Refraction*, by Frank E. E. Germann and Charles F. Metz; *Colorado Rusts of Woody Plants*, by Paul F. Shope.

*University of Colorado, Boulder, Colorado.* $1.00. 10 x 6¾; 57; 1940 (paper).

## MORPHOLOGY

CONTRIBUTIONS TO EMBRYOLOGY. *Publication No. 518. Volume XXVIII, Nos. 170 to 178.*

*Carnegie Institution of Washington, Washington, D. C.* $4.00 (paper): $5.00 (cloth). 11¾ x 9; iii + 451 + 34 plates; 1940.

The present issue of this valuable series contains the following papers: (1) Growth and development of the chimpanzee, by A. H. Schultz. This study is based on monthly measurements on two chimpanzees of different sex (the male was measured for a period of 4 years; the female, for 5½ years), something over 100 preserved or fresh bodies, and 90 skeletal specimens. Of great value were the fetal and new-born animals. The paper includes much tabular material, 11 figures, and 3 plates. (2) The placentation of *Procavia capensis* with a discussion of the placental affinities of the Hyracoidae (7 plates, 1 graph), by G. B. Wislocki and O. P. van der Westhuysen. Eighteen pregnant uteri, 8 of which consisted of graded stages of embryos from the limb-bud stage up to fetuses of 70–90 mm. crown-rump length, formed the basis of this work. (3) Growth in vitro of ovarian germinal epithelium (two plates), by J. Herman Long. Whole new-born mouse ovary rather than fragments of adult mouse ovary yielded the best results. (4) Development of the neuromuscular spindle in human fetuses (4 plates), by Fidel Cuajunco. The ages of these fetuses were from 10 to 15 weeks, and older. (6) Studies of the reproductive system of the alligator. IV. Observations on the development of the gonad, the adrenal and the Müllerian duct (4 plates), by T. R. Forbes. (7) A volumetric analysis of young human embryos of the 10- and 12-somite stage (4 plates [2 colored] and 6 text figures), by E. A. Boyden. (8) Defective development of the cerebral cortex involving symmetrical bilateral areas (3 plates), by P. A. M. F. Fitz-Gerald. (9) Menstruation in intraocular endometrial transplants in the rhesus monkey (7 plates, 1 text figure), by J. E. Markee. (10) The maturation of "excitability" in the precentral gyrus of the young monkey (*Macaca mulatta*) (33 text figures), by Marion Hines and E. P. Boynton. Literature lists accompany each paper. As is always the case with these publications, the illustrations are very fine.

DEVELOPMENTAL ANATOMY. *A Textbook and Laboratory Manual of Embryology. Fourth Edition, Revised.*

*By Leslie B. Arey. W. B. Saunders Co., Philadelphia and London.* $6.75. 9¾ x 6½; ix + 612; 1940.

As a result of a policy of the author not to revise his book until major additions and improvements could be offered, the present volume represents almost a complete change from previous editions (cf. Vol. 6, p. 242, and Vol. 10, p. 110 of this Review). We now have an authoritative work encompassing the latest developments culled from the world literature on embryological research. The combined references, appended to the chapters, total over 600.

Part I features the germ cells and fertilization, cleavage, germ layers, placentation, and general considerations as to growth and external form. The main body of the text concerns organogenesis, subdivided according to the three germ-layer derivatives. Throughout the book the reference is to human development except where a point may be clarified by

introducing phylogenesis or the embryology of some other mammal. The discussion of each organ contains an account of anomalies that frequently occur.

The laboratory manual details the development of successive stages in the chick and pig embryos, giving adequate instructions for the techniques to be employed in examining each. This section is a decided improvement over the corresponding material in earlier editions. In the book as a whole, 450 drawings and a number of tables have been added. The index covers twenty-five triple-columned pages.

BAILEY'S TEXT-BOOK OF HISTOLOGY. *Tenth Edition.*

*Edited by Philip E. Smith, Russell L. Carpenter, Wilfred M. Copenhaver, Charles M. Goss and Aura E. Severinghaus. William Wood, Baltimore.* $6.00. 9 x 5¾; xviii + 764; 1940.

No feature which has made Bailey's *Histology* such a widely accepted text and reference through nine previous editions has been subtracted from the present volume. It remains a detailed and authoritative description of the tissues of the several organ systems. Preluding the systematic survey are chapters on the fundamental structural unit of all living matter, the cell, and also an entirely new section on the salient features of developmental anatomy. More detailed descriptions of organo-genesis are presented at the conclusion of each organ or system studied.

Although the book has been revised and brought up to date throughout, the principal alterations have occurred in the description of nervous tissues. A brief chapter on organization has been added, and the discussion of the central nervous system has been somewhat shortened.

Probably the main feature which has given this volume such vitality is that it treats histology as a vital subject. Structure is considered always in relation to physiological activity. Since pathological conditions can be understood only with a thorough background of normal structure and function, this book will prove of great value to students and practitioners. In the present edition selected references have been added to each chapter and there are a number of new illustrations.

THE MICROSCOPIC ANATOMY OF VERTEBRATES. *Second Edition, Thoroughly Revised.*

*By James I. Kendall. Lea and Febiger, Philadelphia.* $3.75. 9¼ x 5⅞; 342; 1940.

This book is intended to present to college students a working knowledge of vertebrate microscopic anatomy. The book meets its purpose in that the text is simple, didactic and well-illustrated. It might have indulged with great profit, however, in the luxury of at least some slight discussion of current problems in the field, particularly those that concern the correlation of structure and function. The illustrations are simplified—perhaps too much so in some cases—but not well-labelled. The chapter on technique may be helpful to beginning students. The list of titles in the bibliography is taken exclusively from recent American periodicals. It is unfortunate that the excitement of many of the provocative titles does not find its way into the text.

ATLAS OF OUTLINE DRAWINGS OF THE DOGFISH SHARK, THE NECTURUS, AND THE CAT FOR VERTEBRATE ANATOMY.

*By Samuel Eddy, Clarence P. Oliver and John P. Turner. John Wiley and Sons, New York; Chapman and Hall, London.* $1.50. 11 x 9; [6] + 77 drawings; 1940 (paper).

This volume contains many good outline drawings of the organ systems of various animals used in the laboratory and is supplementary to the laboratory manual (cf. Q. R. B., Vol. 15, p. 249) by the same authors. The drawings are fortunately unlabeled, thereby enabling the student to exercise a little ingenuity.

## PHYSIOLOGY AND PATHOLOGY

THE UNIVERSE THROUGH MEDICINE.

*By J. E. R. McDonagh. William Heinemann (Medical Books), London.* 25s net. 9⅝ x 7¼; v + 389; 1940.

The title of the book does not overstate the author's ambitious undertaking. There is a prologue and an introduction, followed by six chapters called respectively, the First, Second, Third . . . Sixth Circles. The subheadings of these chapters are: From the beginning of activity undergoing condensation of the birth of the atom: From the birth of the atom to that of the molecule; Chemical combination; The colloid state; The vegetable kingdom; The animal kingdom. There is an epilogue and a bibliography of 44 book references but no detailed literature citations.

In the introduction the author states: "My studies in this field [skin and venereal diseases] led me to conclude that most of the so-called 'skin diseases' are manifestations of disease caused by what I term 'intestinal toxaemia.'" The author is untrammeled by established definitions or by the limitations of experimental technique or by the results of experimental studies. Such terms as hydration and dehydration are used repeatedly in ways which mystify the biochemist as to his meaning. The following quotations selected at random will serve to give the prospective reader an idea of the flavor of the book:

> The interaction between opposing products I refer to as "inter-particular disharmony" in contra-distinction to the "intra-particular disharmony" which may occur between the bricks in a product.
>
> "Activity" is the name I give to the form of matter others call "energy." Calcium functions as a radiator and completes a cycle of chemico-physical changes with sodium, for it is the janitor to the dehydration which the protein particles undergo and consequently is the guardian of regress.
>
> The main natural function of the seventeenth element [chlorine] is that of binder, as it connects sodium to the protoplasm of cells and to the protein particles in the plasma and potassium to the nucleus of cells and to the red blood-corpuscles.
>
> The phorphorus individual is tall, thin, nervous and susceptible to external impressions. This element in potency is useful in the last stage of an acute illness such as pneumonia, for example.

Such quotations could be extended to hundreds. The entire book suggests the language of the astrologer rather than that of the scientist. The author is to be commended for his sustained energy, vivid imagination and enthusiasm.

OBESITY AND LEANNESS.

*By Hugo R. Rony. Lea and Febiger, Philadelphia.* $3.75. 9¼ x 6; 300; 1940.

In the preface the author points out that although the scientific literature of obesity and leanness is rich in papers dealing with the various pathological and clinical aspects of the problem, as well as with summaries and reviews of the available material, no comprehensive presentation of the subject has appeared since v. Noorden's monograph on obesity in 1900. All who are aware of the extent and nature of this literature are aware that during the past forty years many new facts have emerged which show that obesity and leanness involve more than a balance between calorie intake and output.

In this scholarly discussion of the literature the author gives an excellent account of the physiology of fats and adipose tissue. Then the pathogenesis of obesity and leanness is discussed under the following chapter headings: The caloric balance; The endocrine system; The nervous system; The intermediary metabolism; Lipophylia; Heredity; and a Résumé; the hemeostatic body weight regulation. Part III treats the clinical aspects of obesity and leanness. Froehlich's syndrome, the pineal syndrome, Cushing's syndrome, Dercum's disease, Laurence-Biedl disease, Schueller-Christian syndrome, Morel syndrome, and v. Gierke's syndrome are discussed from the basis of diagnostic procedure. Other chapter headings in this section are: Clinical pathology of obesity; The therapy of obesity; Classification and diagnosis of leanness; The therapy of primary leanness.

The author has rendered a useful service in gleaning from the widely scattered medical, physiological, and biochemical literature the contributions of recent decades which relate to obesity and leanness. Everyone who desires to keep informed in these fields will find the book highly useful.

PHYSIOLOGY OF MICTURITION. *Experimental and Clinical Studies with Suggestions as to Diagnosis and Treatment.*

*By Orthello R. Langworthy, Lawrence C. Kolb and Lloyd G. Lewis. Williams & Wilkins Co., Baltimore.* $3.50. 9 x 6; viii + 232; 1940.

The original work which forms the basis of this monograph was reported in the literature by the authors and their collaborators during the period 1933 to 1940. The present systematic account of the anatomy, pharmacology, physiology and clinical neurology of the urinary bladder provides a welcome integration of their studies with those of earlier investigators in this insufficiently understood field. The book, with its 258 bibliographic citations, should prove useful to all interested in the subject.

Perhaps the most stimulating aspect of the work is the suggestion that smooth muscle, as exemplified by the urinary bladder, "has as complicated a representation in the brain and spinal cord as striated muscle, and one which appears to be similar in the principles of its actions." In support of this thesis the authors present evidence for a stretch reflex mechanism in the detrusor muscle which is under control of suprasegmental tone-maintaining and tone-inhibiting centers. These are located at the same levels of the neuraxis as are the analogous mechanisms for the control of stretch reflexes in skeletal muscle.

It would be of interest to apply the authors' views concerning the neurological control of the bladder to other smooth muscle organs. Certain experimental facts suggest that this might be particularly profitable in the case of the gastrointestinal tract. If this were done the result should constitute a sufficient comment on the present volume.

BACILLARY AND RICKETTSIAL INFECTIONS, *Acute and Chronic. A Textbook. Black Death to White Plague.*

*By William H. Holmes. The Macmillan Co., New York.* $6.00. 9¼ x 6⅛; [12] + 676; 1940.

No more adequate conception of this important book can be given than by quoting from the author's preface:

"... the mere accumulation of facts [the plan of most textbooks], however valuable they may be in actual practice, cannot be regarded as an ideal form of education." The medical student should find time "to study medicine as it has slowly evolved, and thus learn really to understand the relation of medicine to the growth of civilization." "... he would realize that there are few medical 'discoveries', but that rather our present knowledge represents the cumulative experience of many generations of priests, physicians, physicists, and philosophers, the painstaking study and observations of many centuries."

The subject matter is presented with the idea of sharpening the critical faculties of the student while acquiring habits of thinking and study; "of his becoming a man of wide interests and broad vision, and, eventually, perhaps of his becoming an educated physician." Numerous quotations are given from the writings of other men. The volume, reflecting the type of instruction now being given in courses of Internal Medicine at Northwestern Medical School, is intended to furnish sufficient material for the work of one quarter of the course in didactic medicine. It deals only with the bacillary and rickettsial infections, leaving the virus diseases, and the infections of coccal, spirochetal, and protozoal etiology for subsequent presentation.

In order to save space, no illustrations are given, but the sections are carefully documented and an excellent index has been provided.

FOODS AND NUTRITION: *A Guide for Use with the Instructional Sound Film "Foods and Nutrition."*

*Prepared by Melvin Brodshaug and W. Hugh Stickler, in collaboration with A. J. Carlson and H. G. Swann. University of Chicago Press, Chicago.* 15 cents. 8 x 5½; iv + 32; 1940 (paper).

ENDOCRINE GLANDS: *A Guide for Use with the Instructional Sound Film "Endocrine Glands."*

*Prepared by Melvin Brodshaug and W. Hugh Stickler, in collaboration with A. J. Carlson and H. G. Swann. University of Chicago*

*Press, Chicago.* 15 cents. 8 x 5½; iv + 32; 1940 (paper).

Each of these guides presents the script of a sound film bearing the same title. In addition, each contains a short general introduction to the subject and extensive footnotes giving definitions and more precise descriptions of certain phases of the subject not readily adaptable to sound film. *Foods and Nutrition* discusses metabolism and the effects of deficiency in each of the components of the diet. The latter is illustrated by excerpts from the film showing both man and experimental animals. *Endocrine Glands* shows briefly the method of removing portions of endocrine organs and the effect that is produced by the resulting deficiency. In turn the parathyroids, pituitary, pancreas, and thyroid are considered. Because of the brevity and simplicity of these books and films, it is doubtful that they will be of much use except for students of beginning courses.

VITAMINS: *What They Are and How They Can Benefit You.*

*By Henry Borsook. The Viking Press, New York.* $2.00. 8¼ x 5½; xiii + 193; 1940.

VITAMINS FOR HEALTH AND BEAUTY.

*By Mabel Stegner. Home Institute, 109 West 19th St., New York.* 15 cents. 9 x 6; 39; 1940 (paper).

Both of these treatises will be easily understood by the general reader, for whom they are written. The first is by far the more comprehensive. Borsook discusses each vitamin (or vitamin complex) separately, giving some idea of the minimum requirements for the prevention of deficiency diseases, the minimum requirements for top-notch health, some of the best food sources, a brief description of the deficiency diseases, as well as a word about buying the commercial concentrates. Five appendices deal respectively with the chief common sources of the vitamins, daily human requirements for abundant health, examples of a day's food for children and adults at different price levels, menus for children, and the vitamin contents of common foods.

The pamphlet issued by the Home Institute is understandable to anyone who can read a cook-book. The necessary facts are given concerning the function of vitamins, vitamin units found in the usual foods, sample diets, diets for growing children, etc.

PHYSIOLOGY OF THE FETUS. *Origin and Extent of Function in Prenatal Life.*

*By William F. Windle. W. B. Saunders Co., Philadelphia and London.* $4.50. 9⅛ x 6⅛; xiii + 249; 1940.

Wilhelm Preyer's notable monograph *Specielle Physiologie des Embryo* appeared in 1887. Much of the work discussed in this earlier book has been restudied by new experimental methods, and topics which have baffled former investigators are now being solved through the ingenious technical procedures recently perfected. Windle's book is the first effort to collect and integrate the body of knowledge which has accumulated in the field of fetal physiology since Preyer's publication. The material is arranged according to organs and systems, the treatment of the fetal nervous system being particularly stimulating. The final chapter on nutrition and metabolism is brief, as this subject has been adequately covered in Needham's *Chemical Embryology*. Emphasis has been placed throughout on the strictly physiological aspects of mammalian fetal life and no attempt has been made to treat the field exhaustively. The chemistry of the fetus is dealt with "only to the point of supplying the reader with brief up-to-date synopses for the sake of completeness." However, this book should be found useful not only to physiologists and embryologists, but also to neurologists, psychologists, and pediatricians. Bibliographies are appended to each chapter and an index and illustrations have been provided.

THE ENDOCRINE FUNCTION OF IODINE.

*By William T. Salter. Harvard University Press, Cambridge; Oxford Uni-*

*versity Press, London.* $3.50. 9¼ x 6; xviii + 351; 1940.

The principle underlying the use of burnt sponge by the Chinese in the treatment of goiter as far back as the thirteenth century B.C. remained obscure until the discovery of iodine in 1811. Its subsequent isolation from the thyroid in 1895 led to an understanding of the endocrine function of this element.

Salter's experiences in Harrington's laboratory in London and in Mean's laboratory in Boston have well qualified him for the task of assembling and discussing the essentials of our present knowledge of the relation of iodine to the individual endocrine organs, as well as to the complex functioning of the total endocrine system. The scope of the textual material is indicated by the chapter headings which include: Iodine stores in body tissues; Circulating iodine; Thyroid activity; Iodine and the pituitary-ovarian axis; Iodine balance; etc. Written in a completely technical and authoritative manner, the volume will undoubtedly be welcomed by clinicians, medical technicians, and endocrinologists alike.

An appendix for laboratory workers, a bibliography of 588 titles, and a complete subject index are provided.

EXPERIMENTAL INVESTIGATIONS ON THE RESPIRATORY FUNCTION IN DIVING MAMMALS AND BIRDS. *Hvalrådets Skrifter, Scientific Results of Marine Biological Research Nr. 22.*

*By P. F. Scholander. Jacob Dybwad, Oslo.* Kr. 12.00. 10¾ x 6¾; 131; 1940 (paper).

In this monograph the author reviews the literature on prolonged and deep diving of mammals and birds and adds many experiments of his own. His investigations include determinations of respiratory metabolism and of blood chemistry in seals, beavers, penguins, ducks, and porpoises, during and after submergence. The most striking results are the bradycardia in the diving mammals during diving and the increase of lactate in the blood following the dive. The author concludes from his findings that there is a shunting of the blood from the muscles during diving and that this differential vasomotor control is an important adjustment for prolonged diving. There is a short bibliography, a section on methods, and an appendix giving complete numerical findings of the author's experiments. There is no index. The author is to be congratulated for overcoming the technical difficulties in obtaining quantitative results on the respiratory activity of the diving mammals and birds.

COMPLETE GUIDE FOR THE DEAFENED.

*By A. F. Niemoeller. With a Foreword by Harold Hays. Harvest House, New York.* $3.00. 8 x 5½; 256; 1940.

HANDBOOK OF HEARING AIDS.

*By A. F. Niemoeller. With a Foreword by Harold Hays. Harvest House, New York.* $3.00. 8 x 5½; 156; 1940.

The first of these books discusses, in 77 brief chapters, the structure of the ear, the various causes of deafness and other hearing defects, care of the ear, education of the hard of hearing, advice on getting the most out of conversation, lectures, movies, etc. The second describes all kinds of hearing aids, with information on the principles underlying their construction and purposes, their advantages or disadvantages, by whom they are manufactured, and, in some cases, their price. Both books are recommended as authoritative by the president of the American Association for the Hard of Hearing, Dr. Harold Hays, who contributed the introductions.

Chapter 76 of the *Complete Guide for the Deafened* consists of a list of books, excluding the medical, on hearing and deafness. Neither book is indexed.

BIRD MALARIA. *The American Journal of Hygiene Monographic Series, No. 15, July, 1940.*

*By Redginal Hewitt. The Johns Hopkins Press, Baltimore.* $1.10. 9 x 5¾; xvii + 228; 1940.

The many recent advances made in the

study of bird malaria are brought together in this monograph and so enables "information relative to the materials, methods and results in the entire field" to be found in one source. That such a task is valuable is obvious not only because of the intrinsic interest that the study of avian plasmodia has *per se*, but more so from the standpoint of the effect that this branch of malariology has had on the development of human malaria research. The similarity of the bird species of *Plasmodium* to that of human makes for suitable experimental techniques and controls otherwise impossible.

The geographical distribution of the parasites, host records, experimental methods and laboratory techniques, characteristics of infections, pathology, immune reactions, chemotherapy, mosquito transmission are but part of the contents. Many charts, tables, figures and a bibliography of over 500 references, make this critical review an invaluable contribution to the study of malaria.

A Guide to Human Parasitology *For Medical Practitioners. Fourth Edition.* *By D. B. Blacklock and T. Southwell. Williams & Wilkins Co., Baltimore.* $4.00. 9½ x 6; viii + 259; 1940.

Although written principally for the medical practitioner, this book in its previous editions (cf. Q. R. B., Vol. 14, p. 261 for mention of third edition) has found widespread acceptance among students and public health workers. The present rewriting embodies recent findings on several parasitic orders.

The authors assume that the reader has little or no previous experience in the diagnosis of parasitic diseases and start with a consideration of the necessary equipment and techniques for analysis. In turn follow concise descriptions of the various pathogenic species of protozoa, flatworms, and roundworms, including for each species the distribution, habitat, salient diagnostic characters, life histories, and clinical manifestations of the infection. These characteristics are presented in tabular form in the final chapter as are also the numerous vectors in the spread of the organism. Such systematic descriptions facilitate the learning of a large body of data. This, coupled with a thorough index, makes for an excellent guide for the medical man or reference for the student.

Life and Death at Low Temperatures. *By B. J. Luyet and P. M. Gehenio. Biodynamica, Normandy, Missouri.* $4.50. 9½ x 6½; 341; 1940.

In this monograph the authors discuss the effect of low temperatures on animals and plants. The subject matter is divided into three parts: the first deals with the killing power of low temperatures, the second with the physical effects of cold on protoplasm, and the third with theories of cold injury and of death. Many references are given although the comments about these references are exceedingly uncritical. No attempt has been made to cover the practical application of these studies to food preservation or to related fields. Each part has a separate bibliography and, at the end of the book, there is a special bibliography giving the references in chronological order. There is a subject and an author index. This monograph is to be recommended to anyone wishing to find reference material on the effect of cold on biological material or to obtain a review of the theories proposed to explain cell injury and death at low temperatures.

The American and His Food. *A History of Food Habits in the United States.* *By Richard O. Cummings. University of Chicago Press, Chicago.* $2.50. 8 x 5¼; xi + 267; 1940.

A summary account is presented of the evolution of dietary habits in this country from 1789 to date. The material has been drawn from diaries, travel accounts, cookbooks, newspapers and other contemporary documents. The factors which have influenced the changes in customs are many, as the author clearly points out. They include social, economic, and geo-

graphical elements as well as fads and science. The most interesting chapters are those that deal with the effects of the fluctuating medical viewpoints about nutrition on the beliefs of the people and the good use that commercial enterprises have made of the scientific endeavors. Although as a history this work constitutes only a fragmentary discussion of the subject it is well and amusingly written and is based on sound facts.

MAN, MICROBE, AND MALADY.

*By John Drew. Penguin Books, Harmondsworth and New York.* 25 cents. 7 x 4¼; 218; 1940 (paper).

In this little book for the layman emphasis is placed on the disease-producing actions of bacteria and on common-sense precautions which can be taken to prevent infection. It is not likely that it will engender germ-phobia, as the author fears; rather, it seems to this reviewer that it will have the opposite effect, by showing that headway is being made against disease, and that there is also a great deal that individuals can do to help in the fight against epidemics. The chapter on bacterial warfare is timely.

A SURGEON EXPLAINS TO THE LAYMAN.

*By M. Benmoschè. Simon and Schuster, New York.* $3.00. 9¼ x 6¼; [8] + 317; 1940.

Believing that the layman should have available to him a non-technical account of some of the things surgeons can do, Benmoschè has described the everyday operations that everyday men and women are likely to require at some time or other in their lives. The book does not contain what the doctor tells the patient as he or she is being persuaded to make the voyage from home to hospital and to operating room. It contains what the patient-to-be would like to know well in advance of the earliest symptoms of disease. The book is clearly and simply written, and it should be helpful to anyone whose fears can be dispelled by comprehension.

MORE YEARS FOR THE ASKING.

*By Peter J. Steincrohn. D. Appleton-Century Co., New York and London.* $2.00. 7⅜ x 5; xii + 218; 1940.

The lay reader will find in these pages advice on the upkeep of his health. The case studies on the prevention of such common diseases as tuberculosis, diabetes, diseases of the blood and blood vessels, heart trouble, cancer, stomach trouble, etc. emphasize the importance of a periodic medical check-up and the intelligent cooperation between patient and physician.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 47, No. 1. Endocrine and Developmental Studies of Gonopod Differentiation in Certain Poeciliid Fishes. I. The Structure and Development of the Gonopod in Platypoecilus maculatus,* by Clifford Grobstein.

*University of California Press, Berkeley.* 25 cents. 10¼ x 6¾; 18 + 1 plate; 1940 (paper).

## BIOCHEMISTRY

CHEMICAL METHODS FOR THE STUDY OF RIVER POLLUTION. *Fishery Investigations, Series I. Vol. IV, No. 2. Ministry of Agriculture and Fisheries.*

*By C. H. Roberts, J. Grindley and E. H. Williams. British Library of Information, New York; H. M. Stationery Office, London.* 60 cents. 10½ x 7¼; 36 + 1 plate + 1 folding chart; 1940 (paper).

This monograph gives a number of procedures to enable the chemist in the field or in the laboratory to determine the concentrations of the various chemicals and chemical compounds present in polluted waters. Methods for the determination of dissolved oxygen, combined chlorine, ammoniacal nitrogen, nitrous nitrogen, free carbon dioxide, free chlorine, cyanide, hydrogen sulphide, tar acids, tar bases, arsenic, iron, lead, dissolved solids, and pH value are given in detail. The tech-

niques to be used in obtaining a representative sample of the water are discussed. An appendix gives alternate procedures for the determination of ammoniacal and nitrous nitrogen by means of a Hellige comparator. A table is included for obtaining saturation concentrations of dissolved oxygen, expressed in parts by weight per 100,000 of water, at pure temperatures and concentrations of chloride. There is also included a chart for the determination of dissolved oxygen. A short bibliography and an index are appended.

DIE METHODEN DER FERMENTFORSCHUNG. *Lieferungen 2, 3, and 4.*

*Edited by Eugen Bamann and Karl Myrbäck. Georg Thieme, Leipzig.* Lief. 2, RM. 22.80; Lief. 3, RM. 29.40; Lief. 4, RM. 30.60. 11 x 8; Lief. 2, 173–476; Lief. 3, 477–868; Lief. 4, 869–1276, 1940 (paper).

These volumes are the continuation of an extraordinarily comprehensive yet readable work (cf. Vol. 15, p. 503 for notice of the first part) by an international group of contributors who summarize the preparation and behavior of biological compounds and the modern physico-chemical techniques applicable to enzyme research.

Volume II deals with the specific preparations and behavior of the carbohydrates, nucleic acids, proteins and their degradation products, cellular reductants, and with RSH and RSSR compounds. In Volume III are discussed the methods (enzymatic, X-ray, absorption spectra, polarographic, dielectric constant, micromelting point, etc.) used in the determination of structure. The use of nomography, redox potentials and free energies as aids to enzyme study are explained. Volume IV deals with the application of the methods described in the preceding volume in following enzyme reactions. Numerous quantitative chemical micromethods are given. In addition, general discussions on the preparation and examination of biological materials are presented.

THE VITAMIN $B_1$ CONTENT OF FOODS IN TERMS OF CRYSTALLINE THIAMIN. *U. S. Department of Agriculture. Technical Bulletin No. 707.*

*By Lela F. Booher and Eva R. Hartzler. Government Printing Office, Washington.* 5 cents. 9⅛ x 6; 20; 1940 (paper).

The method chosen in the present study for assaying the thiamin content of common human foods is a comparison of weight gains in standardized $B_1$ fed rats with those fed a specified amount of the food in question. The literature on this and other methods is briefly reviewed. A detailed description is given of the methods of preparation of both the basic diet and of the food samples along with the statistical techniques of analysis. Approximately 100 foods are included in this report, and it is estimated that the ascribed number of units of thiamin are accurate to within 20 per cent. In view of the care with which the study was undertaken, the assays are probably well within this limit.

LABORATORY MANUAL OF BIOCHEMISTRY. *By Benjamin Harrow, Gilbert C. H. Stone, Harry Wagreich, Ernest Borek and Abraham Mazur. W. B. Saunders Co., Philadelphia and London.* $1.50. 9 x 6; v + 119; 1940 (paper).

The experiments outlined in this manual are presented with an explanatory preface to each, and illustrated directions are then given in great detail to insure a maximum of success to the student's experiment. The manual is designed for use with the senior author's *Textbook of Biochemistry* (cf. Q.R.B., Vol. 16, No. 1) or a similar text. It is bound with a reagent resistant cover. Bibliographic references and a fairly complete index are provided.

## SEX

CONTROLLED FERTILITY: *An Evaluation of Clinic Service.*

*By Regine K. Stix and Frank W. Notestein. Williams & Wilkins Co., Baltimore.* $3.00. 8¼ x 5½; xiv + 201; 1940.

The group studied in detail consisted of 1497 women patients of the Birth Control Clinical Research Bureau (Margaret Sanger, Director) in New York City, between January 1, 1931 and June 30, 1932, and who were still living in the Bronx at the time they were later visited (July, 1932 to May, 1934). The report falls into four divisions: (1) a description of the group studied and a consideration of the representiveness and accuracy of the data; (2) reproductive experience (in absence of contraception, prevalence and effectiveness at attempts at contraception, and pregnancy wastage) before clinic attendance; (3) reproductive experience after clinic attendance; and (4) a consideration of some of the implications of the findings for clinic policy and management, public health and population problems. Details of methods and procedures and master tables have been put in appendices, thus freeing the text from cumbersome details not immediately necessary for an understanding of the analyses. Although the study is based on a small and atypical section of the population (but one that is gradually expanding to the proportion of a "national movement"), it is an important beginning to intensive investigations that will be necessary for an adequate assessment of the rôle of the birth control clinics in therapeutic and preventive medicine.

The bibliography covers seven pages and there is an index.

HOPOUSIA *or The Sexual and Economic Foundations of a New Society.*

*By J. D. Unwin. With an Introduction by Aldous Huxley. Preface by Y. J. Lubbock. Oskar Piest, New York.* $4.00. 9¼ x 6⅛; 475; 1940.

At the time of his death in June, 1936, Unwin was at work on a sequel to his *Sex and Culture* which was published in 1934. Little more than half had been put in final draft. This, together with new chapters that have been formed from those of his notes that were sufficiently full, and some unfinished fragments, are here published under the title *Hopousia* (derived from the Greek word for *where*). In the introduction Aldous Huxley states:

> [this book] treats at length of a single question: What are the conditions which must be fulfilled if a society is to go on displaying maximum energy for an indefinite period? In order to answer this question, one must, according to Unwin, discover a solution to two specific problems. First, a way must be found for making a good deal of sexual restraint indefinitely acceptable to at least the ruling classes of a society. Second, it is necessary to discover an economic system which does not, as ours so manifestly does, interfere with the display of energy, but rather fosters and encourages it. In *Hopousia*, Unwin presents his solution to these two problems.

In a series of ten appendices are given notes left by Unwin on such subjects as determinism, the influence of canon law, Hopousian economic structure, etc. A bibliography and an index are provided.

MODERN MARRIAGE *A Handbook for Men. Second Edition.*

*By Paul Popenoe. The Macmillan Co., New York.* $2.50. 7½ x 5; xi + 299; 1940.

This second edition (first edition noticed in Q.R.B., Vol. 2, p. 144) represents a rather complete revision of the author's well-known text. While the sub-title would indicate that it is a guide for men in the art of choosing their wives and initiating a family, it is in reality a book of information for both men and women on the problems of pre-marital and marital relations. Moreover, it is far above the average of this kind of book because the advice, judgments and conclusions of the author do not in general derive from ethical considerations but in considerable amount are based on observations. For some time Popenoe has pioneered in the development of applied social biology in the field of marriage. As in all such pioneering efforts his work is not above criticism; nevertheless it represents a start which deserves to be encouraged and extended to other fields of social intercourse. An adequate list of references is included.

SEX-MORALITY TOMORROW.

*By Kenneth Ingram. George Allen and Unwin, Ltd., London.* 6s. net. 7⅛ x 4¾; 175; 1940.

The present war, the author believes, will mark "the close of a period in history, the collapse of the phase of civilization in which we have grown up" and that "any attempt to deal with the problems of sex-life must therefore take into calculation a radically altered society." His speculations as to what the new sex-morality will be do not deviate greatly from the present trend, nor do they present much that is essentially new concerning attitudes toward homosexuality, masturbation, and sex-life in schools. "The moral philosophy of the new world will certainly hesitate to suggest anything of the nature of legislation, for it will always bear in mind how varied are the characteristics, the needs, the inclinations of human beings."

THE PHYSIOLOGY OF SEX AND ITS SOCIAL IMPLICATIONS.

*By Kenneth Walker. Penguin Books, Harmondsworth and New York.* 25 cents. 7 x 4¼; 157; 1940 (paper).

In presenting the subject of sexual relationships to the lay reader the author uses the teachings of Freud, Havelock Ellis, and Marañon for his basic tenets. The questions of sex differences, preparation for marriage, problems of sex and marriage, sex and education, and sexual deviations are covered. The section on sex and education is perhaps the best portion of the book. It should help parents to overcome their own shyness in the teaching of sex to their children. The discussion of the correlation necessary for the effective teaching of sex in school and home is adequate.

## BIOMETRY

STATISTICAL METHODS *for Medical and Biological Students.*

*By Gunnar Dahlberg. Interscience Publishers, Inc., New York; George Allen and Unwin, London.* $2.75. 8½ x 5½; 232; 1940.

The arrangement of material and statistical techniques employed in this book are much the same as those found in numerous other recent texts. It differs in that it attempts to explain statistical methods and concepts in words, necessitating a modicum of mathematical knowledge. This may be a benefit to those so unfortunately limited, but the excessive use of words which could more concisely be expressed in symbols may prove irksome, if not confusing, to persons with mathematical capabilities. Although the fundamentals of probability, centering constants, variation, correlation, and skewness are adequately treated, there is little consideration of curve fitting and nothing on graphical methods or life table functions. The emphasis throughout has been on the medical aspect of statistics and almost without exception the examples have been drawn from this field. Hence the volume will find its widest acceptance by medical and public health workers. There is no list of references, but short tables of probability and an index are included.

A TREATISE ON ALGEBRA. *Vol. I. Arithmetical Algebra. Reprinted from the 1842 Edition. Vol. II. On Symbolical Algebra and Its Applications to the Geometry of Position. Reprinted from the 1845 Edition.*

*By George Peacock. Scripta Mathematica, Yeshiva College, New York.* $6.50 for the two volumes. 8¼ x 5⅛; Vol. I: xvi + 399, Vol. II: x + 455; 1940.

Ordinarily, a textbook on algebra would not be reviewed in a journal such as this, but a facsimile reprint of a classic of this type should be called to the attention of scientists in general. Peacock's beautiful development of the algebraic operations profoundly influenced other students in that field, and his treatment of the subject is a delight, when contrasted with the

careless approach that we find in so many of our modern texts.

This book is strongly recommended to any biologist who considers himself a dilettante in the field of mathematics.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. Volume 3, Number 2, June, 1941.

*Edited by N. Rashevsky. University of Chicago Press, Chicago.*

This number contains the following papers: Weber's theory of the Kernleiter, by Alvin M. Weinberg; The dynamics of cell constriction during division, by N. Rashevsky; A theory of steady-state activity in nerve-fiber networks: I. Definitions and preliminary lemmas, by Alston S. Householder; Studies in the mathematical biophysics of discrimination and conditioning. II. Special case: errors, trials, and number of possible responses, by H. D. Landahl; Electrical charges and potentials in cells resulting from metabolism of electrolytes, by Robert R. Williamson.

STATISTICAL METHODS. *Applied to Experiments in Agriculture and Biology. Third Edition.*

*By George W. Snedecor. Iowa State College Press, Ames, Iowa.* $3.75. $8\frac{7}{8}$ x $5\frac{3}{4}$; xiii + 422.

This is the second revision of this book since the first edition appeared in 1937 (1st edition noticed Q.R.B., Vol. 13, p. 376; 2nd edition, Vol. 14, p. 264. Although it follows the previous editions closely, it contains some new material in the chapters on linear regression and on large samples of enumeration data, and a completely new chapter on design and analysis of samplings. The book is of especial use to agricultural experimentalists, and presents the methods principally in terms of examples in this field.

PUNCHED CARD METHODS IN SCIENTIFIC COMPUTATION.

*By W. J. Eckert. Thomas J. Watson Astronomical Computing Bureau, Columbia University, New York.* $2.00 (cloth); $1.75 (paper). $9\frac{1}{2}$ x $6\frac{3}{4}$; ix + 136; 1940.

Although the author has selected his applications from the field of astronomy, this book will be of interest to any person concerned with the application of punched card equipment to such arithmetic operations as the construction of tables of tabular function, interpolation, mechanical quadrature, numerical harmonic analysis, and multiplication of series.

WIDTH—WEIGHT TABLES *For Boys and Girls from 1 to 17 years—For Men and Women from 18 to 41+ Years. Second Revised Edition.*

*By Helen B. Pryor. Stanford University Press, Stanford University, Calif.; Oxford University Press, London.* 75 cents. 11 x $8\frac{1}{2}$; 15; 1940 (paper).

This is the second revised edition of these well-known tables (cf. Q.R.B., Vol. 11, p. 366 for mention of 1st edition). The tables are subject, in part, to the errors that are inherent in central-value reasoning, since the regression equation is set up on an individual basis, and the tables are made up in but three broad classes of thoracic lateral width.

## PSYCHOLOGY AND BEHAVIOR

THE PSYCHOLOGY OF FEAR AND COURAGE.

*By Edward Glover. Penguin Books, Harmondsworth and New York.* 25 cents. 7 x $4\frac{1}{2}$; 128; 1940 (paper).

The material in this little book was originally put together to be broadcast to the British people during the summer of 1940. The main thesis is that the morale of any country is its secret weapon, that Hitler is attempting to break this morale and that it is necessary to counter this by learning to deal with the "fifth column

in our own minds." Glover distinguishes between real fears which are to be met by vigorous preparation to meet real danger and by communal activity and close association with others, and unreal fears generated by rumor and vague suspicions. He discusses the reactions to dangers of people of various temperaments—the passive reaction in the overanxious, the moody and depressed who feel they can't escape so why try, the aggressive who are always running into danger, the curious, the claustrophic, etc. In the chapter, "Every man his own psychologist," he gives practical suggestions for mental first-aid in states of acute fright. For those who become overactive, from simple agitation and jumpiness to rage and violence he recommends simple sedative measures—a cigarette, weak tea or an aspirin tablet; for those who become underactive, faint or stuporous, stimulants such as coffee or a piece of candy. There is an interesting chapter on women in war-time, based on the observation that men tend to react to their country as though it were their family while women react to their family as though it were their country. In a chapter on hate and its effect on morale, Glover describes hate as an influence which blurs thinking and spoils judgment at a time when self-control is most necessary. He feels that hate is most apt to appear in an inactive population. There is danger in leaning towards another extreme too, however, and developing guilty consciences at the enemy's shouts of previous injustices, and doubts "that do some credit to our hearts but not our heads." Consciences, he states, were never meant to function at the pistol point. This matter-of-fact, simply written book is an interesting contribution to the practical and currently important problem of civilian morale.

PSYCHOTHERAPY: *Treatment that attempts to improve the condition of a human being by means of influences that are brought to bear upon his mind.*

*By Lewellys F. Barker. D. Appleton-Century Co., New York and London.* $2.00. 7½ x 5; ix + 218; 1940.

In this small book Barker writes about psychotherapy and the psychobiological approach to patients primarily as they are related to the general practice of medicine. He states:

"Many physicians are so markedly repelled by the language and the ideas of some of the writers on psychotherapy (especially on psychoanalysis), that they feel that a subject so apparently recondite can be of but little value in ordinary medical practice and can be safely ignored." This attitude Barker feels is unjustified. He states: "Much of the lack of success in the treatment of patients lies in (1) failure to make a sufficiently thorough diagnostic study, or (2) failure, after comprehensive diagnostic study, to plan the therapy so as to include all the remedial agencies that are indicated by the whole situation of the patient."

Barker strongly advocates treatment of the patient as a person in every case, and in chapter V, "Methods of psychotherapy," outlines the main concepts and practices of present-day psychotherapy, not with erudite detail but in simple, practical terms. The material is descriptive rather than didactic, and offers the reader who has not specialized in psychiatry an opportunity to gain some orientation on what the psychotherapeutic field comprises. Chapter VI presents a brief discussion of psychotherapy in organic conditions. In Chapter VII there is a general survey of the types of therapeutic approach to the different functional disorders, the psychoneuroses and psychoses. Chapter VIII contains a rather oversimplified consideration of psychotherapeutic problems of the different age periods. This is not a book from which the physician trained in psychiatry will obtain special insight, but it would seem to fill the purpose for which it is intended, of indicating to other fields of medicine how psychotherapy may be a useful tool in his therapeutic armamentarium.

There is an adequate bibliography, and an index.

THE ORIENTATION OF ANIMALS. *Kineses, Taxes and Compass Reactions.*

*By Gottfried S. Fraenkel and Donald L. Gunn. Clarendon Press, Oxford and Oxford University Press, New York.* $6.00. 8⅝ x 5⅜; vi + [2] + 352; 1940.

The term *orientation* is used by the authors in its broader sense to include the elementary reactions of animals to stimuli such as light, temperature, and humidity and the equilibrium of animals in relation to gravity. This is the first comprehensive account of the subject in English since Jacques Loeb's work *Forced Movements, Tropisms, and Animal Conduct* was published in 1918.

In the first part of the book Gunn has reorganized Kühn's classification (*Die Orientierung der Tiere im Raum*, published in 1919) of the various types of reaction by which animals become orientated with reference to a stimulus. The second, and more detailed, part treats the conditioning stimuli, with discussions on their type, possible modes of action, and descriptions of the set-up and manipulation of experiments, which were performed chiefly on invertebrates. Many examples and illustrations accompany the discussions. The authors have attempted in both the classification and discussion, to adhere as strictly as possible to the objective, in contradistinction to the anthropomorphic, viewpoint.

This is a highly technical work in a limited field of research but has been prepared in a readable manner. Although the reader may not agree with all the deductions and philosophical beliefs the authors have advanced as to how bedbugs, ants, worms and their ilk find their way about, he will find it a very valuable reference work. The extensive documentation and an index add to its usefulness.

A Review of the Psychoneuroses at Stockbridge.

*By Gaylord P. Coon and Alice F. Raymond. Austen Riggs Foundation, Stockbridge, Mass.* $2.00. 9 x 6; xii + 299; 1940.

This book presents a review of the clinical work of a twenty-five-year period (1910–1934) at the Austen Riggs Foundation, Stockbridge, Massachusetts. Of the 5300 cases treated during this period, a sample of 1060 cases is analyzed, with emphasis on the method of treatment and results obtained. Both case studies and statistical approaches are used. The material is presented in three parts. In Part I, the physical set-up of the Foundation is described, the concept of psychoneurosis as a manifestation of failure to adapt to the ordinary demands of life is delineated, and the therapeutic technique of reeducation presented. Ninety-two cases are briefly reviewed and the observation made that the best results were obtained in individuals who had previously demonstrated themselves to be capable, talented and successful. In Part II, the statistical approach as a method of research in evaluating psychiatric data is discussed. Analyses of data from the Stockbridge records pertaining to sex, age at admission, marital condition, education, occupation, length of stay, number of revisits, physical disease, discharge condition and present mental condition are presented. Part III is devoted to a general summary of the entire study. There are five appendices, including six pamphlets which comprise the course of study in psychology given each patient. A brief bibliography is appended. The study is of interest as an informative presentation of the attitudes and *modus operandi* of the Stockbridge group.

The Neuroses in War.

*Edited by Emanuel Miller. With a Concluding Chapter by H. Crichton-Miller. The Macmillan Co., New York.* $2.50. 8 x 5⅛; xii + 250; 1940.

This excellent book, of multiple authorship, is a concise, practical and informative contribution to the literature of psychiatry in wartime. It presents in a matter-of-fact way a digest of the opinions and impressions of the authors, largely derived from their clinical experiences in the war of 1914–1918. Chapter I giving a survey of the literature of neuroses in war, provides a comprehensive preliminary orientation for the reader. In the succeeding chapters various prominent topics of interest are considered in more detail: mode of onset, differential diagnosis,

and treatment. Place of treatment, methods of treatment and techniques of psychotherapy are discussed and evaluated. It is notable that in only one chapter are theoretical concepts of psychopathology taken up, and here the orientation is also around the military situation and the handling is lucid. There is one chapter on psychiatric organization in the services and one chapter devoted to the problem of civilian morale. There are four appendices, a bibliography and an index. This book should be carefully read by every physician with military responsibilities.

THE HUMAN MIND. *The Key to Peace and War.*

*By Alfred Hook. Watts and Co., London.* 8s. 6d. net. 8½ x 5½; x + 303; 1940.

The aim of the author in writing this book and his conclusions can perhaps best be expressed in his own words:

> It has been our object to inquire into the nature of Mind as the controller of all human activity, to note the part it plays in the more important spheres of life, and to learn why it is that, in spite of the boasted intelligence and the wonderful scientific achievements of the present day, Mind has driven the world to the edge of the abyss.
>
> We have reached the conclusion that desire, or the power to desire, is the main active principle in the mental life of man; and that it is desire that has shaped, and will shape, human destiny according to the objects to which it is directed.

For the development of his thesis the author reviews critically the thoughts of psychologists and philosophers, and presents ideas of his own, on the nature of the animal and human mind, the relations between emotion and intellect, the nature of human nature, etc. There is also a chapter on education in which the emphasis is placed on a redirection of interests of certain ambitious types so that they will be satisfied in more peaceful channels of endeavor. Neither bibliography nor index has been provided.

FROM THIRTY YEARS WITH FREUD.

*By Theodor Reik. Translated by Richard Winston. Farrar and Rinehart, Inc., New York and Toronto.* $2.50. 8½ x 5½; xi + 241; 1940.

This book, by one of Freud's former pupils and ardent disciples, consists of four quite unrelated parts. Part I, Freud and his followers, contains more about Freud and less of the author, and is the most interesting part of the book. Although the author writes with a breathless, reverential attitude of hero-worship towards "the master" for whom it is "our duty and our glory" to carry on, this part of the book contains observations of interest about Freud as a person. The author also offers certain dogmatic opinions about psychoanalysis which place him in a rather isolated position in relation to present-day viewpoints. For instance, he feels that a medical education is an inadequate background for the analyst (he himself is a Ph.D.) but he admits that Freud felt that he was too dogmatic on this point. Parts II and III are essentially essays commenting on various views and writings of Freud which do better speaking for themselves. Part IV consists of six essays written as birthday presents to Freud and are of sentimental rather than scientific value.

WHY MEN BEHAVE LIKE APES AND VICE VERSA *or Body and Behavior.*

*By Earnest A. Hooton. Princeton University Press, Princeton, Oxford University Press, London.* $3.00. 8½ x 5½; xxv + 234 + 10 plates; 1940.

This latest book by Professor Hooton embodies the five Vanuxem lectures which he delivered at Princeton in 1940. It consists of sketches on the distinctive traits of primates and of the principal human racial groups. From the academic viewpoint these sketches present nothing new and startling although the characteristic discursive style in which they are written and the sharp comments that accompany the factual information will appeal to the scientist as well as to the layman. The "harangue on human affairs", as the author entitles his introductory remarks which deal with the present needs of society, constitutes the most significant

part of this work even though the author is swayed somewhat by emotions in discussing the war.

THE RELATIONSHIP BETWEEN AGE AND THE STRENGTH OF HUNGER MOTIVATION. *Comparative Psychology Monographs, Volume 16, Number 4, Serial Number 83.*

*By S. E. Margolin and M. E. Bunch. The Johns Hopkins Press, Baltimore.* 75 cents. 10 x 6¾; 34; 1940 (paper).

The investigation reported in this monograph represents an experimental attack on the problem of the relationship between age and strength of hunger motivation in white rats under certain experimental conditions. The animals were starved for varying periods. Varying intensities of electrical obstruction were then placed between them and food. Thirty-six groups, of 20 rats each, were used. It was found that there is an inverse relationship between age and maximal strength of hunger drive. Other interesting results are also reported. The study is well carried out and reported. There is a bibliography of 20 titles.

THE TERROR OF THE LEOPARD MEN.

*By Juba Kennerley. Stanley Paul and Co., London.* 16s. net. 8½ x 5½; 255 + 4 plates; 1940.

Those who believe that the soul of men and animals can unite at some cryptaesthetic plane and there pass from one into the other, will find numerous observations and personal experiences in this book to substantiate their beliefs. It is all about cockatoos discovering opal mines, hares leading lost prospectors home, about werewolves and were-moose, leopard men, talking leopards, etc., that apparently abound in the wilds of various continents. Were it possible to digest the stuff without too much intestinal disturbance, the result would be a fairly good, but overlong, series of yarns.

## DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

A PHILOSOPHY OF SCIENCE.

*By W. H. Werkmeister. Harper and Bros., New York and London.* $4.00. 8½ x 5¼; xii + 551; 1940.

THE PROMISE OF SCIENTIFIC HUMANISM *Toward a Unification of Scientific, Religious, Social and Economic Thought.*

*By Oliver L. Reiser. Oskar Piest, New York.* $4.00. 9¼ x 6; xviii + 364; 1940.

There is an oft quoted simile from the writings of Newton about a child gathering pebbles on the shore, in which the pebbles represent man's knowledge of the universe and the boundless ocean represents that which is as yet unknown.

As science advances it pushes the limits which circumscribe it back into the erstwhile domain of philosophy, but in so doing it does not curtail the activity of that faculty. Instead, it actually enlarges its scope. It has often been said that for every question science is able to answer it asks ten new ones, and speculation about the answers to these, to be intelligent, must be based upon a reasonable philosophy. In life it is often necessary to make decisions before the evidence is entirely in, so such speculation is desirable even though there be as many philosophies as philosophers.

Thoughts such as these underlie both of the present books, but in the first the problem of the synthesis of science and philosophy is attacked from different directions. Werkmeister is a philosophical scientist, and although he disclaims being a vitalist there is nothing in his work to which the orthodox vitalist is likely to take exception. On the other hand, his reiteration of the inadequacies of mechanistic philosophy is likely to excite the disapproving opposition of that school of thought. Werkmeister's personal feeling is that it is possible to steer a neutral course between Scylla and Charybdis to a third alternative, but being a scientist he makes no attempt to define this *tertium quid*. He lays the foundation for such definition, however, by expounding with clarity and in detail the revolutionary contributions to modern thought that began with the rejection by Lobatschew-

sky of Euclid's *Parallel Postulate* and which since have begun to transform even psychology and sociology. Interested readers may be grateful for Werkmeister's lucidity of expression.

Reiser is by way of contrast, rather a scientific philosopher. He advances an original doctrine to supersede both vitalism and mechanism which he calls humanism—an unfortunate name, as it has already done duty for three different systems, one of which is now pretty generally discredited, and the remaining two of which are so unlike that it is difficult for any one brought up on Aristotelian tradition to conceive of how they may be reconciled. The basis of Aristotelian logic is the law of identity, which teaches that of the two statements A is B, and A is not B, one is necessarily true and the other equally necessarily false. But Reiser's philosophy is essentially one of reconciliation, and by means of an analogy that involves modern relativity physics as well as that of the classical period he demonstrates how A can be B and be not B at the same time. Whether or not he expects in some such way to accomplish the synthesis of his own humanism with the older philosophical systems that have born the same name, he makes it clear that he believes the present time ripe for the formulation of a new logic to replace that of the Stagirite which he believes to constitute the greatest obstacle in the path of further scientific advance.

While the reviewer recognizes the importance of freeing scientific thought from the shackles of an outgrown logic, he believes that the attempt to do so by substituting another would be to jump from the frying pan into the fire. That the progress of science must be orderly and logical is obvious, but to render science subject to any logic, even a good one, would be to restrict its development.

Reiser's work is characterized by a toleration of the opinions of other writers with whom he does not see eye to eye, and it can be recommended to other philosophers as an example of how to write.

Both works are copiously indexed.

FROM THE STONE AGE TO CHRISTIANITY. *Monotheism and the Historical Process.* *By William F. Albright. The Johns Hopkins Press, Baltimore; Oxford University Press, London.* $2.50. 9 x 6; xi + 360; 1940.

In this study the author presents a chronological and geographical picture of the development of man's idea of God from prehistoric antiquity to the time of Christ, places this development in its historical context, and analyzes the historical patterns emerging from the vast amount of accumulated detail. The setting of the book is restricted to the Egypto-Mesopotamian area since "there is no focus of civilization on the earth that can begin to compete in antiquity and activity with the basin of the Eastern Mediterranean and the region immediately to the east of it."

The first two chapters are basic ones, fundamental to the reader's understanding of the author's philosophy of history and to his use of archaeological data. Chapter I treats of the history of archaeological research, the discovery and methodology of the interpretation of written documents of the ancient Near-East, unwritten documents (artifacts, uninscribed monuments etc.), and the oral and written transmission of history. Chapter II is devoted to a survey and analysis of the schools of thought on the philosophy of history. The author presents his own classification of historical stages from early and middle Palaeolithic, in the first stage, to the sixth stage *circa* 1500. The fourth stage (circa B.C.–700A.D.) in this classification

> reflects the author's conviction that the Graeco-Roman civilization of the time of Christ represented the closest approach to a rational unified culture that the world has yet seen and may justly be taken as the culmination of a long period of relatively steady evolution. It was in the fifth century B.C. that we find the greatest single burst of intellectual and aesthetic activity that the world has ever known, with results unparalleled before or after, from the standpoint of the integral achievement of man as intellectual, aesthetic, and physical animal. . . . It was, moreover, about the same time that the religion of Israel reached its climatic expression in Deutero-Isaiah and Job, who represented a height beyond which pure ethical monotheism has never risen.

The following four chapters treat of the development of the idea of God and the

relation between God and man in their historical context. Chapter III is devoted to a survey of prehistory and the ancient Near East; Chapters IV and V, to Israelite monotheism and the prophetic or reformation movement; Chapter VI, to the Hellenistic Age and Jesus the Christ.

In the epilogue the author briefly recapitulates the theory of organismic philosophy in the light of the historical development of monotheism as presented in this text. Notes on the separate chapters, a key to abbreviations of journals and books, and an index are included.

CHESAPEAKE BAY COOK BOOK. *Bayfood Edition.*

*By Ferdinand C. Latrobe. Illustrated by Yardley. Horn-Shafer Co., Baltimore, Md.* 50 cents. 8½ x 5½; [48]; 1940 (paper).

THE EPICURE IN CHINA. *Eight Complete Chinese Epicurean Dinners.*

*The Colt Press, San Francisco.* $1.50. 4¾ x 6; 63; 1939.

These two booklets, both attractively illustrated, furnish many interesting and dependable recipes. The first, dealing with familiar sea food now readily procurable in most parts of the United States will appeal to a wider group than the second.

The place of honor in the *Chesapeake Bay Cook Book* is given to terrapin and turtles, with only four ways of preparing them. But the oyster, crab and many fishes are represented by numerous excellent recipes, only to be tried to be found very palatable. Lobster, scallops, and shrimps are included because they are always in the Maryland markets and are used extensively. Although most of these recipes have been in use for generations in the Chesapeake region their origin in many cases is unknown.

That Chinese food is being increasingly used in this country is evident by the fact that it is now possible to obtain so many of the ingredients in tins. In *The Epicure in China* we find several of our favorite dishes and many that we hope to try. We were unaware, however, that cornstarch [our abomination] is so widely used in the preparation of Chinese food.

CHAMBERS'S TECHNICAL DICTIONARY. *Comprising terms used in Pure and Applied Science: Medicine: the chief Manufacturing Industries: Engineering: Construction: the Mechanic Trades. With Definitions by recognised Authorities.*

*Edited by C. F. Tweney and L. E. C. Hughes. The Macmillan Co., New York.* $5.00. 8 x 5¾; vi + 957; 1940.

This dictionary containing many thousands of technical terms and abbreviations, covering the subjects (from acoustics to zoology) under the broad headings indicated in the sub-title, will be found extremely useful by scientists, manufacturers, technicians, editors, teachers, students, and the technically-minded general reader. In addition to the strictly technical terms which do not ordinarily form a part of every-day speech, many common terms such as *accuracy*, *apple*, *capitalist*, and *speed*, which have acquired special meanings in one or another branch of science, have been included. All the definitions, many of which have been formulated for the first time, are by specialists in their respective subjects. Tables of chemical terms, periodic systems, igneous rocks, sedimentary rocks, the vegetable and animal kingdoms, and a bibliography arranged by subject, are appended.

SCIENCE IN PROGRESS. *Second Series.*

*By L. J. Stadler, F. W. Went, J. F. Fulton, Douglas Johnson, Alfred C. Lane, H. P. Robertson, Carl D. Anderson, Duncan A. MacInnes, J. W. Beams, and J. C. Hunsaker. Edited by George A. Baitsell. Yale University Press, New Haven; Oxford University Press, London.* $4.00. 9¼ x 6; xii + 317; 1940.

Those who take part each year in the national Sigma Xi lectureships in various places from the Atlantic to the Pacific coasts deserve more auditors than any of them have. The publication of their lectures makes available to readers as well as hearers some exceptionally interesting syntheses. These lectures are not given by specialists who lack perspective, but by leaders who are capable of giving to others full and rounded views of their fields.